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## Oregon Agricultural College

## Experiment Station

# The Preparation of Spray Materials

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# FOREWORD

The successful production of orchard and certain farm crops depends, in a large measure, upon the quality of the spray materials used to control insect pests and fungous diseases.

The quality of the sprays depends upon the procedure followed and the care exercised in the preparation of the spray materials.

This bulletin outlines methods of procedure for the preparation of sprays, emphasizes precautions that should be taken in the selection of materials from which the sprays are prepared, and advises on safe mixtures that may be used in combination sprays.

Methods are given for the preparation of lime-sulfur solution, self-boiled lime-sulfur, Oregon cold-mix lime and sulfur, New Jersey dry-mix lime and sulfur, bordeaux mixture, "boiled" lubricating oil emulsion, and three different formulas for "cold" lubricating oil emulsions.

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# The Preparation of Spray Materials

By

R. H. ROBINSON

The introduction of new spray materials, the improvement of those in present use, and the prevalent custom of employing combination sprays, give rise continually to problems that must be solved in order to obtain best results in the orchard. Most of these troublesome problems are caused by chemical reactions that either reduce the efficiency of the spray material or form a by-product that causes foliage burn or other harmful effects. Observations of these chemical reactions under laboratory conditions have, in many instances, disclosed means of overcoming the difficulties.

The purpose of this bulletin, therefore, is to report the best methods by which our common spray materials may be prepared, what combinations are safe, and what precautions should be taken to insure best results. Comments, also, are made on certain commercial spray preparations.

## ARSENATE OF LEAD

There are two forms of arsenate of lead that have been used as insecticides. They are known chemically as lead hydrogen or lead acid arsenate and basic or neutral lead arsenate. Investigations at the Oregon Experiment Station and in other states have shown that the lead hydrogen arsenate is more toxic to insect pests than basic lead arsenate, and consequently the production of the latter has been discontinued by most manufacturers. The basic lead arsenate, therefore, is rarely offered for sale in Oregon and if so it is plainly labeled to distinguish that form from the commonly used lead hydrogen arsenate.

High grade lead arsenate must be high in total arsenic for optimum killing efficiency, low in water-soluble arsenic in order that foliage burn may be reduced to a minimum, and free from foreign impurities. Since most manufacturers have perfected their processes for the production of lead arsenate, high grade material is the rule on the market. The chemical analyses of various brands of lead arsenate sampled in different parts of the state are given in Table I.

TABLE I. ANALYSES OF DIFFERENT COMMERCIAL BRANDS OF LEAD ARSENATE

| Brand | Lead oxide (PbO) | Arsenic oxide ($As_2O_5$) | Water-soluble arsenic oxide ($As_2O_5$) |
|---|---|---|---|
| | % | % | % |
| A | 63.82 | 31.80 | 0.06 |
| B | 63.96 | 32.53 | Trace |
| C | 63.19 | 31.64 | 0.04 |
| D | 64.14 | 32.19 | Trace |
| E | 64.41 | 31.27 | 0.06 |
| F | 63.87 | 32.36 | Trace |
| G | 65.71 | 30.46 | Trace |
| H | 64.86 | 30.75 | 0.12 |
| I | 63.93 | 32.07 | 0.17 |
| J | 63.74 | 32.94 | 0.07 |
| K | 64.41 | 31.84 | Trace |
| L | 63.74 | 31.04 | 0.16 |

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The above results indicate that there are only slight differences in the composition of the various brands. The low water-soluble arsenic content of all samples further emphasizes the high degree of purity of the commercial brands that are now on the market. We can conclude, therefore, from these and numerous other analyses, that from the standpoint of their chemical composition all present brands of lead arsenate are high grade and safe for general use. Equally efficient results may be expected from any of them.

**Recommended combinations.** Lead arsenate may be combined with bordeaux mixture, nicotine sulfate, "cold prepared" oil emulsions, and either the self-boiled, cold-mix, or dry-mix lime and sulfur.

When combined with liquid lime-sulfur the latter should be diluted to spraying strength and one pound of hydrated lime or casein spreader to each 100 gallons added. Finally just before application the lead arsenate should be sifted into the spray.

## LIME-SULFUR

Lime-sulfur is the most important of the sulfur sprays. It is an efficient contact poison for certain scale insects and an important fungicide for several fungous diseases.

The concentrated lime-sulfur solution having a Baumé test of 28° to 32° may be obtained usually from local dealers or association quarters. If not or where used in large quantities it may prove advantageous to prepare it at home. On account of the high cost of transportation the home-prepared or the association product has largely superseded the commercial product having a concentration of 33° Baumé.

**Home preparation of lime-sulfur.** Care should be exercised in the preparation of lime-sulfur in order to obtain as complete a reaction as possible between the lime and sulfur and to prevent the formation of excess sludge.

As a general rule the ingredients are used in the following proportions:

| | |
|---|---|
| Sulfur (powdered) | 2 pounds |
| Quicklime | 1 pound |
| Water | 1 gallon |

Ordinarily 50 gallons or more, depending upon facilities, is prepared at one time. When the lime-sulfur is to be cooked over a fire the following procedure will be found most practicable. Place in a large kettle or feed-cooker 50 pounds of high-grade quicklime and add about 15 gallons of water. When the lime is slaking vigorously add 100 pounds of powdered sulfur and mix rapidly and thoroughly with the lime. Add water (preferably hot) gradually to prevent lime from drying out during the process of slaking. As soon as all the lime is well slaked and a uniform mixture of the slaked lime and sulfur has been obtained, add enough hot water to bring the total volume to 65 or 70 gallons. Continue boiling for 45 minutes, stirring occasionally and adding hot water at intervals to keep the volume at 65 to 70 gallons. Allow to cool and protect the solution from the air. (It is necessary to protect the lime-sulfur from the air since it is easily oxidized to a less toxic form. The best method is to pour enough lubricating or engine oil over the surface to form a thin film.)

If steam is available, quantities may be prepared limited only by the size of vessel used. For a 50- to 200-gallon outfit a circular, perforated steam coil should be placed on the bottom of the vessel and a mechanical agitator with sweeping arms rotating on a shaft should be fitted at the bottom and in the center of the vessel. A half-inch-mesh wire screen cut to fit the vessel is supported by blocks 4 inches above the bottom. The agitator revolves between this screen and the bottom of the vessel.

To prepare 50 gallons proceed as follows: Place 50 pounds of the quicklime on the screen and add sufficient hot water to start the lime slaking rapidly. While the lime is slaking add 100 pounds of powdered sulfur and enough hot water to make a total of about 50 gallons. Turn on the steam, start agitator and cook about 30 minutes or until all of the free sulfur has disappeared. Add hot water occasionally if the original volume diminishes during the cooking process.

After the lime-sulfur has cooled and the sludge has settled completely, the clear liquid should be drawn off and the sludge discarded.

More detailed information pertaining to formulas, designs of large and small plants, storage, and other general information may be found in United States Department of Agriculture Farmer's Bulletin No. 1285.

**Precautions.** It is important to use fresh, high grade quicklime and pure powdered sulfur or flowers of sulfur. Since different brands of lime vary each year, in case of question the Chemistry department of the Experiment Station will be glad to give information and assistance.

If a low-grade or an impure quicklime is used, large amounts of sludge will be formed and sulfur will be wasted. Over-boiling or under-boiling also increases the amount of sludge. Strict adherence to the proper boiling period is therefore important.

Care should be taken to maintain the original volume advised, by the addition of more hot water. Too much water is better than not enough.

**Dilution of stock lime-sulfur solution.** Every horticulturist who makes his own lime-sulfur should secure from the druggist a Baumé hydrometer in order to test his stock solutions. Otherwise he will be unable to use the correct amount of water in diluting his spray for application. The commercial lime-sulfur solution usually has the strength marked upon the barrel.

When the Baumé reading has been ascertained, the lime-sulfur may be diluted according to Table II.

TABLE II. DILUTION TABLE FOR LIQUID LIME-SULFUR

| Strength of stock solution | | To make 100 gallons of dilute spray use the number of gallons of concentrated stock lime-sulfur indicated in the columns below and add water to make 100 gallons. | | | | |
|---|---|---|---|---|---|---|
| Degrees Baumé | Specific gravity | 1 Dormant strength for scale clean-up (12 to 100) | 2 Dormant strength for blister-mite and twig-miner (8 to 100) | 3 Early spring spray (3¼ to 100) | 4 Mid-spring spray (2½ to 100) | 5 Late spring spray (2 to 100) |
| | | *gal.* | *gal.* | *gal.* | *gal.* | *gal.* |
| 34° | 1.304 | 11 + | 7½ | 3 + | 2¼+ | 1¾+ |
| 32° | 1.282 | 12 | 8 | 3¼ | 2½ | 2 |
| 30° | 1.260 | 12¾+ | 8½ | 3½ | 2½+ | 2 + |
| 28° | 1.239 | 14 — | 9¼ | 3¾ | 2¾+ | 2¼+ |
| 26° | 1.218 | 15 | 10 | 4 | 3 | 2½ |
| 24° | 1.198 | 16½— | 11 | 4½— | 3¼+ | 2¾ |
| 22° | 1.179 | 18¼+ | 12¼ | 4¾+ | 3¾— | 3+ |
| 20° | 1.160 | 20¾+ | 13¾ | 5½— | 4¼— | 3½ |

Note: Where the + sign is used, employ a little over the number of gallons indicated. Where the — sign appears use scant measure.

**Recommended combinations.** Lime-sulfur may be combined with nicotine sulfate and with lead arsenate when directions are followed as given under lead arsenate.

### Self-boiled Lime-sulfur

The self-boiled lime-sulfur often used as a special spray for peaches or other tender foliage is mainly a mechanical mixture of lime and sulfur. The addition of sulfur to hot slaking lime reacts chemically to a slight degree and tends further to disintegrate the sulfur particle, giving a mixture of milk of lime containing a suspension of very fine sulfur.

A satisfactory product may be prepared if ordinary care is exercised and if fresh, high-grade quicklime and finely ground sulfur or flowers of sulfur are used. The following proportions are used for each 50 gallons:

| | |
|---|---|
| Quicklime | 8 pounds |
| Sulfur | 8 pounds |
| Water | 50 gallons |

The lime is placed in a suitable vessel and about 2 gallons of cold water is added. As soon as the lime begins to slake actively, add the sulfur and mix quickly with the lime. While stirring the mixture constantly, add more water as needed, to maintain a thick pasty consistency. When the boiling has stopped, immediately add enough cold water to cool the mixture. If the mixture is not cooled immediately, chemical reactions occur that may cause the spray to be unsafe for use on peach or other tender foliage. Strain through a burlap strainer into spray tank and dilute to 50 gallons. The spray is now ready for application. Since the spray is a suspension of sulfur in milk of lime, the agitator should be kept going constantly while spraying is in process.

### Oregon Cold-mix Lime and Sulfur

It is often inconvenient to prepare self-boiled lime-sulfur since the process involves care and, especially if large quantities are needed, takes considerable time.

A more simplified procedure has been worked out by the writer at the Oregon Experiment Station that may be substituted for the method outlined above for the self-boiled lime-sulfur or the dry-mix types of sulfur sprays. For making 50 gallons the following ingredients and amounts are recommended:

| | |
|---|---|
| Sulfur (superfine flour) | 8 pounds |
| Hydrated lime | 4 pounds |
| Skim milk | 2 quarts |

**Preparation.** Weigh out the proper amounts of sulfur and hydrated lime and mix them together. It is unnecessary to mix them thoroughly.

Take 2 quarts of sweet skim milk and add an equal amount of water. Pour this onto the sulfur and lime, stirring until a smooth paste is formed, adding more water if the paste becomes too thick.

Finally add several gallons of water and pour through strainer into the spray tank. Fill tank with the required amount of water and the spray is ready for application.

**Precautions.** Less care, perhaps, is required to prepare the above substitute for self-boiled lime-sulfur than for any other spray. If the hydrated lime is not fresh it will not decrease the effectiveness of the spray. The sulfur, however, should be ground superfine. If skim milk is not available whole milk may be used with equal effectiveness. If the milk is only slightly sour it may be used. If information regarding means of preserving milk is desired write to the Chemistry department of the Oregon Experiment Station.

The method is simple and convenient and the cost of materials is the lowest for this type of sprays. It is therefore felt to be worthy of immediate practical tests by growers in comparison with other types of sulfur sprays for summer use.

### Dry-mix lime and sulfur

The New Jersey Experiment Station also has developed an excellent substitute for self-boiled lime-sulfur that has given good results in field experiments. The mixture is composed of the dry materials which may be prepared at any time and used when necessary. The formula used for making 50 gallons of spray is as follows:

| | |
|---|---|
| Sulfur | 8 pounds |
| Hydrated lime | 4 pounds |
| Calcium caseinate | ½ pound |

The above amounts may be proportionately increased or decreased, depending upon the quantity desired.

**Preparation.** Weigh out the proper amounts of sulfur, hydrated lime, and calcium caseinate.

If necessary, sift both sulfur and lime through a small-mesh sieve in order to remove any lumps.

Mix together the three ingredients thoroughly in order to secure a uniform mixture.

**Dilution.** The New Jersey Experiment Station recommends that the dry-mix material be used at the rate of 12½ pounds to 50 gallons of water. Any of the following methods may be used for diluting with water.

*Method 1.* Place the proper amount of material in a barrel, or other container which will hold water. Add water slowly, stirring the mixture until the grains of sulfur are wet and a thin solution is obtained that will pass readily through a strainer into the spray tank. Strain the material into the spray tank after filling it at least one-half full of water. This method is recommended particularly for use with hand outfits or where it is not convenient to have the agitator running when the tank is being filled.

*Method 2.* Wash the proper amount of dry-mix lime and sulfur through the strainer into the spray tank with the agitator running. This method can be used to advantage only where a strong flow of water from an overhead pipe or hose is available. The strainer used should not have more than 12 to 14 meshes to the inch.

*Method 3.* Put the proper amount of dry-mix directly into the spray tank after filling it at least one-half full of water. As in Method 2, the agitator should be running when the dry material is added in order to insure a thorough mixture with a minimum amount of settling. Open up the nozzle or spray-gun and drive a stream of the liquid that is being forced through the hose directly into the dry material as it falls upon the surface of the water in the tank.

**Precautions.** The same care should be exercised in the use of fresh hydrated lime and very fine flowers of sulfur or dusting sulfur as for the other lime and sulfur combinations.

Casein is one of the ingredients of skim milk, and after drying, grinding, and mixing with lime it is sold on the market as calcium caseinate spreader. This may be obtained in Oregon under several trade names such as Spreado, Hood River Spray Co. Spreader, and Kayso.

Sufficient systematic field experiments have not yet been carried out in Oregon to show definitely the fungicidal properties of the substitutes for self-boiled lime-sulfur. It is generally recognized, however, that sulfur is the active ingredient in this class of sprays and satisfactory results should be obtained. The New Jersey Experiment Station, however, reports the dry-mix lime-sulfur as superior to Sulfur Dust, Atomic Sulfur, or self-boiled lime-sulfur. The Oregon cold-mix lime and sulfur should prove equally effective.

**Recommended combinations.** Self-boiled, cold-mix, or dry-mix lime and sulfur may be combined safely with lead arsenate, nicotine sulfate, cold oil emulsions, or bordeaux mixture.

## Other Sulfur Sprays

Besides the lime-sulfur solutions, there are several commercial products in more or less common use. Among them may be mentioned dry lime-sulfur, barium-tetra-sulfid (B.T.S.), and soluble sulfur.

Barium-tetra-sulfid has been shown to be a fairly effective contact poison, but it possesses no distinct advantage over the lime-sulfur solution except that it is in powder form and convenient to handle. Its cost, however, is prohibitive, and consequently it has not been used to any extent in the Northwest.

Soluble sulfur is similar to lime-sulfur except that lye is used instead of lime in its preparation. As a dormant spray it has been found satisfactory, but it has no superiority over the lime-sulfur. It cannot be used as a summer spray or later than the dormant spray since it causes very severe foliage burn.

Dry lime-sulfur is the product obtained in the dehydration of the concentrated lime-sulfur solution. Apparently there is partial decomposition of the polysulfides during the process of manufacture since the percentage of both free sulfur and thiosulfate sulfur is higher and the polysulfide sulfur is lower than the amounts found in the concentrated lime-sulfur solution calculated on a dry basis. The most recent guaranteed composition of dry lime-sulfur at this writing is as follows:

| | Percent |
|---|---|
| Calcium polysulfid | 70.0 |
| Calcium thiosulfate | 5.0 |
| Free sulfur | 10.0 |
| Inert ingredients | 15.0 |

It may be considered therefore that 85 percent of dry lime-sulfur consists of active ingredients and 15 percent of inert materials that are of no value as a spray.

An average analysis for lime-sulfur solution 33° Baumé is as follows:

| | Percent |
|---|---|
| Calcium polysulfid | 30.5 |
| Calcium thiosulfate | 1.5 |
| Water | 68.0 |

A gallon of lime-sulfur 33° Baumé weighs about 10.7 pounds. Calculating the amount of active ingredients from these figures we find that there are 3.47 pounds per gallon.

When dry lime-sulfur is used either for the dormant spray or for the summer sprays it should be applied in amounts equivalent to the liquid lime-sulfur in order to obtain equivalent protection. Since each gallon of lime-sulfur solution contains 3.4 pounds of active ingredients it would take 4.0 pounds of a dry lime-sulfur having 85 percent active ingredients to be equivalent to one gallon of liquid lime-sulfur. Therefore, in making dilutions for the various sprays 4.0 pounds of the dry lime-sulfur should be used for each gallon of liquid lime-sulfur, Baumé 33°, necessary. While this amount is much higher than is recommended by the manufacturer, field experiments carried on in different parts of the country have indicated conclusively the need of using larger amounts than the manufacturers have recommended in the past, particularly when weather conditions favor the development of serious disease epidemics.

## BORDEAUX MIXTURE

Bordeaux mixture was for a long time the most widely used material for controlling fungous diseases of plants. It has been supplanted to a large extent by sulfur sprays and other materials; yet for certain diseases such as apple-tree anthracnose, peach-leaf curl, peach blight, potato late blight, celery blight, etc., bordeaux is still the most efficient and safest preventive known.

The effectiveness of most protective sprays depends to a large extent upon the spreading and adhering properties of the materials. When bordeaux mixture is properly made it adheres well and has excellent spreading properties.

Laboratory experiments substantiated by field tests have demonstrated the superiority of the carefully prepared home-made bordeaux over all commercial brands. Most commercial brands, both paste and powder forms, do not adhere sufficiently well to warrant advising their use for those fungous diseases that require the toxic ingredient to adhere for several weeks for effective control. The commercial product is inferior owing to the fact that in the manufacturing process the gelatinous, colloidal properties, peculiar to a good bordeaux mixture, are destroyed.

Bordeaux mixture is produced when dissolved copper sulfate (bluestone) and milk of lime are poured together. A chemical reaction takes place between them which results in the formation of a voluminous precipitate.

Formulas are generally designated by the proportion of materials used. For example:

4-4-50 formula

| | |
|---|---|
| Copper sulfate (bluestone) | 4 pounds |
| Calcium oxide (stone or quicklime) | 4 pounds |
| Water | 50 gallons |

Other formulas frequently advised for specific purposes are 3-3-50; 3-6-50; 6-6-50; 6-8-50, etc.

In recent years high-grade hydrated lime has been offered on the market, and if properly used it may be substituted for the quicklime.

When the hydrated lime is used about one-third more by weight than quicklime should be taken. The 4-4-50 formula then is as follows:

| | |
|---|---|
| Copper sulfate (bluestone) | 4 pounds |
| Hydrated lime | 5½ pounds |
| Water | 50 gallons |

Other formulas likewise require ⅓ more of hydrated lime than quicklime.

**Stock solutions.** If large quantities of bordeaux are to be used it is best to prepare concentrated stock solutions. A convenient concentration is one pound of lime or one pound of copper sulfate in each gallon of water.

(a) The copper sulfate when in lump form may be dissolved easily by taking a 50-gallon barrel of water and suspending near the surface of the water 50 pounds of the bluestone in a burlap sack. It will dissolve completely after standing about ten hours or over night.

(b) To prepare the milk of lime, slake 50 pounds of quicklime in a barrel by the addition, with constant stirring, of enough water to prevent "burning" or drying of the lime. When thoroughly slaked add water to make 50 gallons.

The stock solutions (a) and (b) each will contain 1 pound of material to 1 gallon of water. If covered to prevent evaporation these will keep indefinitely.

When hydrated lime is used instead of quicklime, weigh out 66 pounds and add enough water to make 50 gallons. This will contain the equivalent of 1 pound of quicklime to 1 gallon of water.

Copper sulfate also may be obtained in powder form. When the powder is used it is unnecessary to prepare a stock solution since any desired amount may be dissolved quickly by sifting and stirring into the quantity of water to be used in making the bordeaux mixture.

**Methods of preparation.** Bordeaux mixture may be made in a satisfactory manner by several different methods, but it is very important to have both the copper sulfate and milk of lime as dilute as possible before combining. The stock solution must never be mixed without first diluting with water. The following methods will give good results using the stock solutions described above. The quantities given below are for 50 gallons of the 4-4-50 formula. If another formula is desired vary the proportions accordingly.

1. Stir up the stock copper sulfate solution thoroughly, take 4 gallons and add 21 gallons of water. (If powdered copper sulfate is used, sift slowly 4 pounds into 25 gallons of water, stirring meanwhile.)
2. Stir up the stock solution of milk of lime thoroughly, take 4 gallons and add 21 gallons of water.
3. Finally pour the diluted copper sulfate *into* the diluted milk of lime, stirring vigorously.

It is preferable to prepare the bordeaux by mixing directly in the spray tank. For a 50-gallon tank and the 4-4-50 formula proceed as follows:

1. Fill the spray tank about half full of water and start the agitator.
2. Pour 4 gallons of the stock milk of lime solution through a 20-mesh strainer into the spray tank.
3. Take 4 gallons of the stock copper sulfate solution, add 21 gallons of water, and pour into the spray tank while the agitator is running.

**Precautions.** 1. Use fresh quicklime or hydrated lime of highest purity. The Chemistry department of the Experiment Station will give information regarding lime.

2. Dilute the stock solution of copper sulfate and milk of lime before combining them and use water as cold as convenient.

3. Follow closely the procedure as outlined above.

4. Do not fail to pass the prepared bordeaux or the milk of lime through a 20-mesh copper wire strainer before using.

5. Bordeaux mixture will attack iron; always use brass or bronze spray rods or connections and copper strainers. Rinse out spray tank, hose, and rod or gun with clean water immediately after using.

**Preservative for bordeaux mixture.** Bordeaux mixture must be applied immediately after preparation. If it is not possible to use all in the tank within three hours after it was made the bordeaux may be preserved by the addition of a very small amount of ordinary sugar. The sugar retards the breaking down of the gelatinous precipitate that is so essential in the formation of a membrane that causes adherence to the surface sprayed.

The tests of the Oregon Experiment Station indicate that ⅛ oz. of sugar should be used for each pound of copper sulfate in the spray. For example, in a 100 gallon tank filled with 4-4-50 bordeaux mixture there were 8 lbs. of copper sulfate used. Therefore, 8 × ⅛ oz. or 1 oz. (1 heaped tablespoonful) of sugar should be used. The required amount of sugar is added after first dissolving in a little water.

**Combination with other sprays.** Bordeaux mixture may be combined safely with lead arsenate, calcium arsenate, paris green, certain mineral oil emulsions, and nicotine sulfate preparations.

When preparing the combination spray always add any of the above materials to the bordeaux mixture after starting the agitator and just before application.

Mineral oil emulsion should be mixed with two times its volume of water before adding *slowly* to the bordeaux mixture.

## BURGUNDY MIXTURE

This spray is sometimes used in place of bordeaux in sprays for small fruits shortly before picking because it does not leave the objectionable deposit on the fruit which comes from applying bordeaux at such a time. Like bordeaux, the active principle is copper but it does not adhere as well as in the case of bordeaux.

**Preparation.** Burgundy mixture may be prepared in the same manner as bordeaux except that sodium carbonate is substituted for quicklime. The following formula is commonly used:

| | |
|---|---|
| Copper sulfate (bluestone) | 2 pounds |
| Sodium carbonate (sal soda) | 3 pounds |
| Water | 100 gallons |

## COMMERCIAL BORDEAUX

There are on the market numerous commercial brands of paste and powder bordeaux mixtures the copper content of which ranges between 10 and 25 percent. As stated previously a favorable recommendation cannot be made for this class of spray materials especially where the spray must adhere for several weeks to obtain effective results.

There are, however, the "two powder" commercial preparations that, if combined according to directions, will give an excellent bordeaux mixture. These should be used in preference to the other type if it is not convenient to prepare the home-made bordeaux.

## MINERAL OR LUBRICATING OIL EMULSIONS

The use of oil emulsions such as miscible oils or mineral oil emulsions was limited until very recently. The Experiment Station has not advised the home preparation of this spray, because more than ordinary care should be exercised in its preparation. On account of its wider use and the comparative high cost in some localities of the commercial product it seems opportune to describe in detail the methods by which oil emulsions may be home prepared by the horticulturist.

It is generally known that oil and water alone will not mix. In order to break up the oil globules an "emulsion" is made with the help of a third substance. The emulsion then may be added to the spray tank and dispersed in a suitable quantity of water in a manner similar to lead arsenate or other diluted spray. The importance of a good emulsion, therefore, is obvious. Recent laboratory experiments have shown that numerous materials can be used as the third substance but only those that are practical will be considered.

Among the first substances commonly used for preparing mineral or lubricating engine oil emulsion is potash fish-oil soap. The formula advised is as follows:

| | |
|---|---|
| Mineral oil | 2 gallons |
| Water (soft) | 1 gallon |
| Caustic potash fish-oil soap | 2 pounds |

**Preparation.** Dissolve the potash soap in the water by heating in a kettle or other suitable vessel that will stand fire. Add the oil and heat to the boiling point. Remove kettle from fire and while still hot pump the mixture into another vessel with a bucket pump or through a spray pump at a pressure of about 60 pounds and then pump it back again. The emulsion, after cooling, is ready for diluting and should mix well with water. If it does not mix well with water repump it.

**Remarks.** The mineral oil may be any of the medium-grade engine oils, but on account of the cost the commonly called red engine oil medium grade is advised. Black fuel oil or similar oils should not be used until experimental studies indicate that no harmful effects will result.

When pumping from one vessel to another the nozzle should be closed to form a fine spray.

### "Cold Oil" Emulsions

The oil emulsion described above may be referred to as a "boiled" emulsion to distinguish from the "cold" emulsions that are prepared without the aid of heat. The latter, *if properly made,* is preferable to the boiled emulsion and does not require as much labor in its preparation. Furthermore, the cold emulsion does not break down easily in hard water.

Several formulas have proved to be successful and slight variations do not seem to influence the quality of the product. Three formulas follow:

Formula 1

| | |
|---|---|
| Mineral oil | 4 gallons |
| Copper sulfate (bluestone) | ½ lb. in 1 gal. water |
| Calcium oxide (quicklime) | ½ lb. in 1 gal. water |

Formula 2

| | |
|---|---|
| Mineral oil | 4 gallons |
| Water | 1 gallon |
| Skim milk | 1½ quarts |
| Hydrated lime | 1 teaspoonful |

Formula 3

| | |
|---|---|
| Mineral oil | 4 gallons |
| Water | 1½ gallons |
| Casein spreader | ½ pound |

**Stock solutions for Formula 1.** Stock solutions of both copper sulfate and lime facilitate the preparation of the oil emulsion especially if several 200-gallon tanks of a 2 percent, or higher, oil spray are to be used in a day. The stock solution of copper sulfate is prepared as directed under bordeaux mixture; that is, 1 pound is dissolved in 1 gallon of water. The calcium oxide likewise is slaked and water added until in the proportion of 1 pound to 1 gallon of water.

**Preparation of Formula 1.** Put 4 gallons of the mineral oil in a half barrel or other convenient vessel.

Take 2 quarts of the stock solution of copper sulfate and add 2 quarts of water. Pour this into 2 quarts of the milk of lime that also has been diluted with 2 quarts of water.

Pour immediately this freshly prepared bordeaux into the oil and pump the mixture back into itself, using a coarse spray of a bucket pump or spray pump. After pumping for a minute or two reduce the opening of the nozzle until a fine spray is obtained and pump into another container. Then pump it back again. This should give a good emulsion; if not, repump it.

**Preparation of Formula 2.** Put 4 gallons of the mineral oil in a half barrel or other convenient vessel. Add the skim milk to a gallon of water and stir in the teaspoonful of hydrated lime or equivalent of slaked quicklime. Pour this mixture into the oil and pump it back into itself as described above. Then reduce the opening of the nozzle until a fine spray is obtained and pump into another container. Then pump it back again. The emulsion should now be ready for final dilution and spraying.

**Preparation of Formula 3.** Make a smooth paste out of the casein by slowly adding water and stirring. Continue adding water until 1½ gallons have been added. Put the oil in a suitable container, add the casein mixture, and pump through spray pump as described above.

**Precautions.** The above emulsions are concentrated material and must be diluted with water before using. To dilute, take the required amount of oil and add an equal amount of water. Stir thoroughly and pour slowly into the spray tank which has the required amount of water for final dilution. The agitator should be started before the emulsion is added.

The emulsions may break down after standing for several hours and consequently should be applied as soon after preparation as possible. The solution may be reemulsified by pumping again, although sometimes it is necessary to add more of the emulsifying agent—bordeaux, milk, or casein depending upon the formula used. An emulsion that has broken down or does not mix well with water must not be used.

Sufficient experimental data are not available to advise definitely regarding the type or grades of oil that will give best control of scale, red spider, or other pest against which oil has shown promise. Thus far the red engine oil has given best results and is recommended at this time.

While pumping, a pressure of at least 60 pounds should be maintained.

In Formula 1, hydrated lime may be substituted for the quicklime. It is important that the quicklime or hydrated lime should be fresh and a high-grade product. When hydrated lime is used one-fourth more by weight should be taken.

Any casein spreader such as sold under the trade names Spreado, Hood River Spray Co. Spreader, or Kayso may be used in Formula 3.

**Recommended formula.** Any one of the formulas may be used, but it is more economical to use certain ones for certain purposes. If a bordeaux oil combination spray is to be applied Formula 1 should be used. For other purposes Formula 2 is advised. If skim milk or whole milk is not available then Formula 3 may be used.

**Combination with other sprays.** Cold prepared mineral oil emulsion may be combined safely with bordeaux mixture, lead arsenate, and tobacco or nicotine preparation. No other combinations are recommended until further experimental observations have been made. Boiled emulsion should not be used with lead arsenate.

The cold emulsion may be used with hard water without breaking down. The boiled soap emulsion, however, is ruined by hard water or small amounts of lime-sulfur.

## COMBINATION SPRAYS

It is economically important to combine two or more sprays for the effective control of insect pests and fungous diseases. Oftentimes it is necessary to apply at a crucial time a combination of a stomach poison, a contact insecticide and a fungicide. Such a combination is a saving in labor and the high cost of spraying is materially diminished. When certain combinations are made, however, chemical reactions take place and may result harmfully in one or more of the following ways:

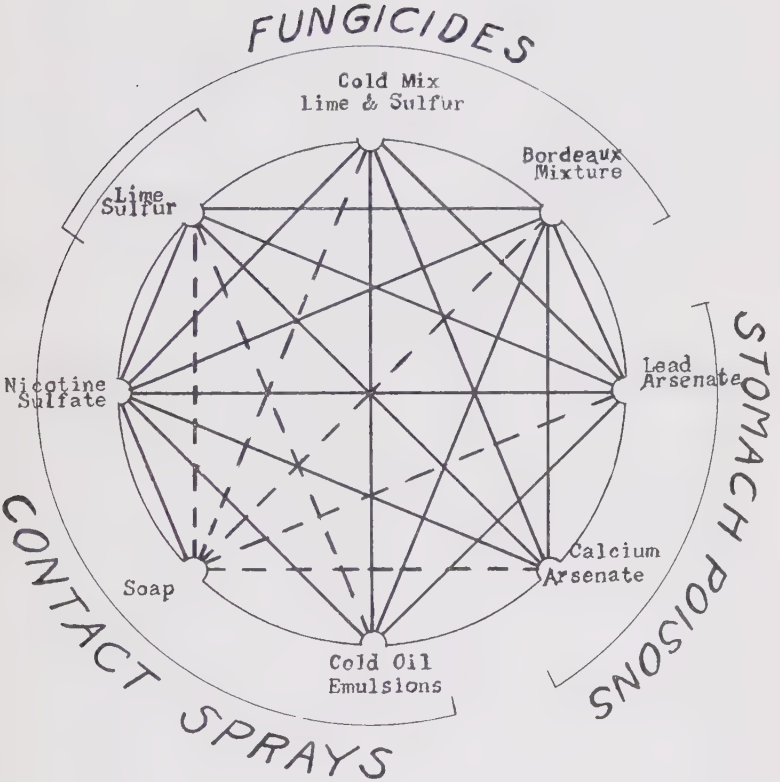
1. Formation of a soluble substance that will cause burning of the foliage or other injury.

2. Complete or partial destruction of the toxic properties the sprays combined.

3. Decrease of the natural spreading and adhering properties of the sprays.

It is very important, therefore, to combine compatible insecticides and fungicides as given under recommended combinations.

The compatibilities of various spray materials are graphically represented in the diagram on page 15.



——— RECOMMENDED COMBINATIONS

— — — DANGEROUS COMBINATIONS

Adapted from Cal.Sta.Cir. #195.
By Geo. P. Gray.

Station Bulletin 202 April, 1924

Oregon Agricultural College

Experiment Station

# The Relation of Humidity to the Texture, Weight, and Volume of Filberts

By

HENRY HARTMAN

1885

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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# SUMMARY

The water content of filberts increases or decreases with the relative humidity of the air in which they are kept. Even within the range of common relative humidities, their water content varies sufficiently to affect materially the texture, weight, and volume and to have bearing upon such handling operations as gathering, drying, grading, and storing. Filberts are susceptible to the attacks of decay organisms and should be gathered and dried as soon as they fall to the ground. Excessive drying is not necessary or desirable. Storing under living room conditions seems to be satisfactory. It does not seem advisable to attempt to keep filberts fresh during the entire storage period. Rather they should be dried down to a safe water content and allowed to regain their moisture only when about to be consumed. Refreshing restores the original texture and plumpness and improves the cracking quality. The use of certain wrapping mediums such as paraffin paper does much to prevent evaporation after refreshing.

# The Relation of Humidity to the Texture, Weight, and Volume of Filberts

By

HENRY HARTMAN

## INTRODUCTION

Very little has been done in this country to gain information relative to the proper handling of filberts. In Great Britain and other European countries where the filbert is better known and appreciated, premium prices are obtained when the product is sold while in a fresh and wholesome condition. In America, on the other hand, the trade for the most part knows the filbert only when it is dry and hard in texture and in many cases stale and damaged by decay organisms. As the filbert industry expands here the consumer will doubtless become more discriminating, and added attention will have to be paid to methods of gathering, grading, drying, and storing, in order that superior quality may be produced.

Preliminary observations in these experiments indicated that under certain conditions, filberts lose moisture when exposed to dry air and gain moisture when subjected to high humidities, the gain or loss being sufficient to affect materially the texture, weight, and volume of the nuts, and seemingly to be of enough importance to have bearing upon handling practices.

## EXPERIMENTAL

### RELATION OF HUMIDITY TO WEIGHT AND WATER CONTENT

To gain information on the relation of humidity to the weight and water content of filberts, it was necessary (1) to obtain a range of constant relative humidities, and (2) to subject filberts to these and ascertain the amounts of water gained or lost during the treatment.

**The method of Regnault and Sorel.** The method employed to obtain the various relative humidities was that of Regnault and Sorel,[1] which in general is based upon the fact that the vapor tension of a mixture of sulfuric acid and water varies with the concentration of the acid. These investigators found that within a rather wide range of temperature, definite relative humidities are maintained over sulfuric acid and water and that a complete series of relative humidities varying practically from 0 to 100 percent can be obtained, provided the proper concentrations are secured. At a temperature of about 20° C., for example, the relative humidity of air above a solution of sulfuric acid and water with a specific gravity of 1.070 was found to be 86 percent, while that above a solution with a specific gravity of 1.460, at the same temperature, was found to be 40 percent.

---

[1] Biedermann, Rudolf, Chemiker-Kalender, pp. 109-110 and p. 113.

Adopting the procedure of the above authors, the following series of relative humidities was obtained for these experiments:

| Specific gravity | Approximate % $H_2SO_4$ | Relative humidity |
|---|---|---|
| 1.000 | 0 | 100 |
| 1.070 | 10 | 86 |
| 1.145 | 20 | 75 |
| 1.213 | 29 | 65 |
| 1.233 | 32 | 60 |
| 1.290 | 38 | 55 |
| 1.335 | 43 | 49 |
| 1.420 | 52 | 40 |
| 1.460 | 56 | 35 |
| 1.840 | 95.6 | 0 |

The concentrations of the acid used were computed for a temperature of 20° C., but variations of 8 to 10 degrees in either direction would not seriously change the relative humidities.[1] Specific gravity in each case was determined by the Westphal Specific Gravity balance. The highest concentration of sulfuric acid used was 95.6 percent, which for practical purposes can be assumed to yield a relative humidity of 0 percent, since actual relative humidity over such acid is less than .0001 percent. Distilled water was used in obtaining the relative humidity of 100 percent. Common, six-inch glass desiccators (Fig. 7) were used for containers. About 300 c.c. of solution was used in each desiccator and the concentration was corrected at intervals during the experiment to offset any change due to the absorption or giving off of water by the filberts.

**Relative humidities over salt solutions.** Other ingredients besides sulfuric acid and water are known to produce varying relative humidities. The air above a saturated solution of sodium chloride (common salt), for example, has a relative humidity of about 80 percent over a wide range of temperatures.[1] This in some respects has advantage over sulfuric acid and was used in certain phases of these experiments.

**Varieties.** Three varieties were used in these tests; namely, Barcelona, Du Chilly, and Nottingham, these being selected not only because of their commercial popularity, but because each is representative of a type of filberts.

**Treatment of specimens.** Typical specimens of Barcelona were divided into ten lots, varying in weight from 117.81 to 131.88 grams each. The specimens of Du Chilly were arranged also into ten lots varying from 102.17 to 109.81 grams each and those of Nottingham were separated into eight lots varying from 88.35 to 90.05 grams each. The original weight of all the lots is given in tables I, II, and III respectively. All specimens used in this part of the experiment were unshelled. The specimens of Barcelona had been gathered for several days and were partly dried. The specimens of Du Chilly had just been gathered and were still more or less green, while those of Nottingham had been kept at living room humidities for some time.

**Determination of water content.** To determine the water content of each lot, the nuts were dried down in the Freas Electric Vacuum oven for 36 hours at a temperature of 90° C. It was found necessary to crush the nuts in order to drive off the water more completely, the crushed nuts giving up from .5 to .8 percent more water than those placed in the oven whole. The dry weight of each lot and its water content expressed in grams and in percents of total weight are given in tables I, II, and III.

TABLE I. WATER CONTENT OF UNSHELLED BARCELONA FILBERTS AT VARIOUS HUMIDITIES

| Lot number | Relative humidity | Percents $H_2SO_4$ | Specific gravity | Weight Oct. 19 | Weight Oct. 26 | Weight Nov. 2 | Weight Nov. 11 | Weight Nov. 19 | Weight Nov. 26 | Dry weight | Water content in grams | Water content in percents |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 0 | 1.000 | 126.44 | 133.70 | 137.41 | 141.92 | 144.02 | 144.32 | 109.40 | 34.92 | 24.2 |
| 2 | 86 | 10 | 1.070 | 118.44 | 120.91 | 122.76 | 124.40 | 124.75 | 124.85 | 102.64 | 22.21 | 17.8 |
| 3 | 75 | 20 | 1.145 | 116.29 | 117.51 | 117.94 | 118.32 | 118.46 | 118.45 | 101.85 | 16.20 | 14.2 |
| 4 | 65 | 29 | 1.213 | 123.59 | 123.65 | 123.42 | 123.42 | 123.44 | 123.44 | 108.35 | 15.09 | 11.4 |
| 5 | 60 | 32 | 1.233 | 125.36 | 125.30 | 124.47 | 124.31 | 123.21 | 123.22 | 109.80 | 13.42 | 10.8 |
| 6 | 55 | 38 | 1.290 | 123.34 | 121.85 | 121.12 | 120.62 | 120.60 | 120.61 | 108.75 | 11.86 | 9.8 |
| 7 | 49 | 43 | 1.335 | 131.88 | 127.91 | 126.54 | 125.92 | 125.81 | 125.79 | 115.20 | 10.59 | 8.4 |
| 8 | 40 | 52 | 1.420 | 121.01 | 115.10 | 113.27 | 112.64 | 112.35 | 112.35 | 106.01 | 6.35 | 5.7 |
| 9 | 35 | 56 | 1.460 | 123.33 | 116.82 | 114.81 | 114.13 | 114.10 | 114.06 | 108.85 | 3.21 | 4.6 |
| 10 | 0 | 95.6 | 1.840 | 117.81 | 107.95 | 105.74 | 104.81 | 104.45 | 104.42 | 102.39 | 2.03 | 1.9 |

TABLE II. WATER CONTENT OF UNSHELLED DU CHILLY FILBERTS AT VARIOUS HUMIDITIES

| Lot number | Relative humidity | Percents $H_2SO_4$ | Specific gravity | Weight Nov. 1 | Weight Nov. 12 | Weight Nov. 21 | Weight Nov. 27 | Weight Dec. 3 | Weight Dec. 8 | Dry weight | Water content in grams | Water content in percents |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 0 | 1.000 | 105.74 | 110.06 | 112.02 | 113.42 | 113.42 | 113.46 | 87.87 | 25.59 | 22.5 |
| 2 | 86 | 10 | 1.070 | 103.49 | 104.10 | 104.48 | 103.37 | 103.41 | 103.40 | 85.82 | 18.02 | 17.4 |
| 3 | 75 | 20 | 1.145 | 102.17 | 101.95 | 101.25 | 101.09 | 101.05 | 101.05 | 86.61 | 14.44 | 14.3 |
| 4 | 65 | 29 | 1.213 | 104.27 | 100.26 | 99.02 | 98.70 | 98.64 | 98.65 | 86.02 | 12.63 | 12.8 |
| 5 | 60 | 32 | 1.235 | 109.81 | 105.13 | 104.12 | 103.60 | 103.60 | 103.60 | 91.39 | 12.21 | 11.2 |
| 6 | 55 | 38 | 1.290 | 109.33 | 101.30 | 99.07 | 98.48 | 98.45 | 98.47 | 88.30 | 10.17 | 10.3 |
| 7 | 49 | 43 | 1.335 | 103.26 | 96.15 | 93.29 | 93.18 | 93.12 | 93.10 | 85.42 | 7.68 | 8.2 |
| 8 | 40 | 52 | 1.420 | 107.96 | 98.12 | 95.49 | 95.46 | 95.45 | 95.45 | 88.87 | 6.58 | 6.8 |
| 9 | 35 | 56 | 1.460 | 109.34 | 97.95 | 94.05 | 94.04 | 94.03 | 94.03 | 88.71 | 5.32 | 5.3 |
| 10 | 0 | 95.6 | 1.840 | 103.87 | 91.32 | 87.19 | 86.96 | 86.96 | 86.95 | 85.39 | 1.56 | 1.8 |

TABLE III. WATER CONTENT OF UNSHELLED NOTTINGHAM FILBERTS AT VARIOUS HUMIDITIES

| Lot number | Relative humidity | Percents $H_2SO_4$ | Specific gravity | Weight Nov. 20 | Weight Nov. 30 | Weight Dec. 11 | Weight Dec. 17 | Weight Dec. 26 | Weight Dec. 29 | Dry weight | Water content in grams | Water content in percents |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 0 | 1.000 | 90.05 | 100.65 | 101.60 | 102.75 | 104.40 | 104.45 | 79.77 | 24.68 | 23.6 |
| 2 | 86 | 10 | 1.070 | 90.01 | 94.28 | 94.36 | 94.74 | 95.77 | 95.80 | 80.50 | 15.30 | 16.0 |
| 3 | 75 | 20 | 1.145 | 88.35 | 90.86 | 90.92 | 91.15 | 91.35 | 91.40 | 79.20 | 12.20 | 13.3 |
| 4 | 60 | 32 | 1.235 | 90.70 | 91.16 | 90.95 | 90.95 | 90.97 | 90.97 | 81.45 | 9.52 | 10.5 |
| 5 | 49 | 43 | 1.335 | 88.95 | 86.97 | 86.84 | 86.70 | 86.64 | 86.60 | 79.75 | 6.85 | 7.9 |
| 6 | 40 | 52 | 1.420 | 89.65 | 87.81 | 86.84 | 86.39 | 86.30 | 86.30 | 81.77 | 4.53 | 5.5 |
| 7 | 35 | 56 | 1.460 | 88.20 | 83.90 | 83.70 | 83.72 | 83.70 | 83.65 | 79.95 | 3.70 | 4.4 |
| 8 | 0 | 95.6 | 1.840 | 89.71 | 83.44 | 82.20 | 81.60 | 81.05 | 81.00 | 79.70 | 1.30 | 1.6 |

From the data presented above, it appears that humidity has a definite bearing upon the water content and weight of filberts. The moisture content of these nuts fluctuates; that is, increases or decreases with the relative humidity of the air in which they are kept. Over the range of humidities employed in these experiments, the water content of unshelled Barcelona varied from 1.9 to 24.2 percent, that of Du Chilly from 1.8 to 22.5 percent, and that of Nottingham from 1.6 to 23.6 percent. Evidently the range of fluctuation is very much the same for the three varieties. Fig. 1 shows graphically the relation of humidity to the weight and water content of Barcelona.

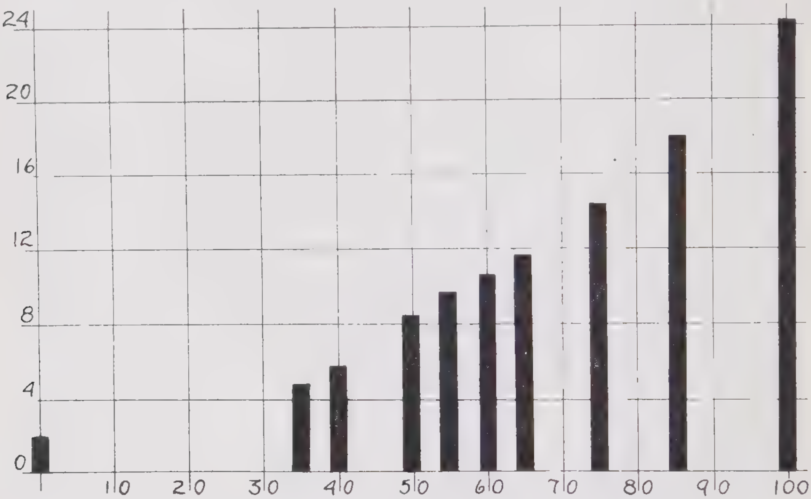


Fig. 1. The relation of humidity to the water content of Barcelona filberts. The vertical column of figures indicates the water content expressed in percents. The horizontal column indicates the relative humidity.

The significance of the high water content, 24.2 percent in the case of Barcelona, which filberts can attain merely from contact with moist air is made apparent when it is pointed out that the green Barcelona contains only about 26.5 percent water and that dried nuts of this variety take on only 26.2 percent water by immersion.

**Reversal of treatment on Barcelona.** The aim of this phase of the test was to ascertain whether the process of gain or loss of moisture is completely reversible throughout the entire range of humidities. Will filberts which are completely dry, in other words, take on as high a percentage of water at high relative humidities as those which are only partly dried before submission to the same humidities, and, conversely, will nuts with a high water content become as dry at low humidities as those which are already more or less dried beforehand?

With this aim in view the treatment of lots 1 and 10 of the Barcelona series was reversed; i. e., lot 1, which had been subjected to a relative humidity of 100 percent, was changed to a relative humidity of 0 percent, while lot 10 was changed from a relative humidity of 0 percent to one of 100 percent. Weighings were made as before until no further gain or loss of moisture was evident. The results obtained are summarized in Table IV.

The data gathered here show that for practical purposes, fluctuation in the water content of filberts is a reversible process. Apparently the previous moisture conditions of these nuts has but little to do with their present or future capacity to gain or lose moisture. Filberts which have been dried down even to complete dryness will take on as much water at high humidities as those which are only partly dried.

TABLE IV. REVERSAL OF TREATMENT ON LOTS 1 AND 10 OF BARCELONA SERIES

| Lot number | Relative humidity | Percents $H_2SO_4$ | Specific gravity | Weight Nov. 26 | Weight Dec. 16 | Weight Jan. 26 | Dry weight | Water content in grams | Water content in percents |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 95.6 | 1.840 | 144.32 | 114.10 | 111.04 | 109.40 | 1.64 | 1.5 |
| 10 | 100 | 0.0 | 1.000 | 104.42 | 125.60 | 134.45 | 102.39 | 32.06 | 23.5 |

## WATER CONTENT OF SHELLS AND KERNELS

The object of this phase of the experiment was (1) to find the respective amounts of water contained by the shells and kernels, and, (2) to determine whether the ratio remains constant throughout the range of humidities.

Barcelona kernels were arranged into 10 lots varying in weight from 43.71 grams to 50.74 grams each. These were subjected to relative humidities varying from 0 percent to 100 percent as in the previous tests. Shells, also of Barcelona, were arranged into three lots of 55.92 grams, 61.19 grams, and 56.18 grams each. These were subjected to relative humidities of 0, 60, and 100 percent. Weighings were made from time to time and the water content was computed as before. The complete data obtained are found in Tables V and VI.

TABLE V. WATER CONTENT OF SHELLED BARCELONA FILBERTS AT VARIOUS HUMIDITIES

| Lot number | Relative humidity | Percents $H_2SO_4$ | Specific gravity | Weight Oct. 19 | Weight Oct. 26 | Weight Nov. 2 | Weight Nov. 11 | Weight Nov. 19 | Weight Nov. 25 | Dry weight | Water content in grams | Water content in percents |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 0 | 1.000 | 46.29 | 52.39 | 54.95 | 57.24 | 57.32 | 57.34 | 41.75 | 15.59 | 27.2 |
| 2 | 68 | 10 | 1.070 | 47.49 | 49.05 | 49.77 | 50.53 | 50.66 | 50.66 | 44.38 | 6.28 | 12.2 |
| 3 | 75 | 20 | 1.145 | 47.30 | 48.01 | 48.22 | 48.52 | 48.60 | 48.63 | 43.95 | 4.68 | 9.6 |
| 4 | 65 | 29 | 1.213 | 50.34 | 50.32 | 50.22 | 50.30 | 50.24 | 50.24 | 46.71 | 4.53 | 7.0 |
| 5 | 60 | 32 | 1.235 | 48.52 | 48.40 | 48.24 | 48.15 | 48.10 | 48.05 | 45.15 | 2.90 | 6.0 |
| 6 | 55 | 38 | 1.290 | 44.39 | 43.41 | 43.06 | 42.95 | 42.95 | 42.95 | 40.64 | 2.31 | 5.7 |
| 7 | 49 | 43 | 1.335 | 50.74 | 49.50 | 49.37 | 49.22 | 49.23 | 49.22 | 47.22 | 2.00 | 4.3 |
| 8 | 40 | 52 | 1.420 | 43.71 | 42.21 | 42.02 | 41.95 | 41.91 | 41.90 | 40.69 | 1.21 | 2.8 |
| 9 | 25 | 56 | 1.460 | 47.18 | 46.18 | 45.44 | 45.31 | 45.29 | 45.29 | 44.17 | 1.12 | 2.5 |
| 10 | 0 | 95.6 | 1.840 | 45.24 | 42.95 | 42.72 | 42.52 | 42.36 | 42.34 | 41.40 | .94 | 2.2 |

Seemingly at ordinary humidities, water in considerable amounts is contained by both the shells and kernels of filberts. Both apparently gain and lose water in accordance with the relative humidities to which they are subjected. The ratio, however, does not remain constant. For

TABLE VI. WATER CONTENT OF BARCELONA SHELLS AT VARIOUS HUMIDITIES

| Lot number | Relative humidity | Percents $H_2SO_4$ | Specific gravity | Weight Oct. 29 | Weight Nov. 10 | Weight Nov. 17 | Weight Nov. 25 | Weight Dec. 4 | Weight Dec. 10 | Dry weight | Water content in grams | Water content in percents |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 0 | 1.000 | 55.92 | 60.15 | 62.70 | 63.27 | 63.93 | 63.95 | 50.31 | 13.64 | 21.3 |
| 2 | 60 | 32 | 1.233 | 61.19 | 62.60 | 62.95 | 63.47 | 63.42 | 63.45 | 55.25 | 8.20 | 12.9 |
| 3 | 0 | 95.6 | 1.840 | 56.18 | 53.18 | 51.97 | 51.40 | 51.21 | 51.21 | 50.72 | .49 | .9 |

example, at 100 percent relative humidity, the kernels took on 27.2 percent water while the shells took on only 21.3 percent. At 60 percent relative humidity, the condition is reversed, the shells containing 12.9 percent water while the kernels contain but 6.0 percent water. At 0 percent humidity the kernels again take the lead and retain 2.2 percent water while the shells retain but .9 percent. The relationship of humidity to the water content of the shells and kernels is shown graphically in Fig. 2.

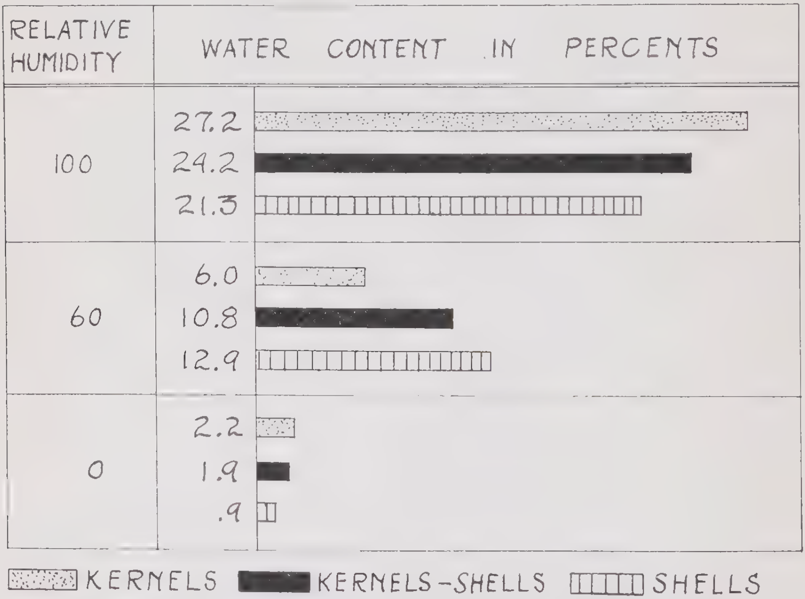


Fig. 2. The relation of humidity to the water content of shells and kernels of Barcelona filberts.

## RELATIVE PERCENTAGES OF SHELL AND KERNEL FOR VARIETIES OF FILBERTS

Since the ratio of the water content of shells and kernels is not constant throughout the range of humidities, it is evident that the percentages of shell and kernel for the different varieties may be misleading.

To obtain a fair comparison of the relative amounts of shell and kernel found with the different varieties, it is necessary to subject all the specimens to a given relative humidity for a period of time so that the water content in each case will be about the same. It would not be fair, for example, to compare the percent of kernel in Barcelona as against that of Du Chilly, if in one case green nuts were used in the calculations while dried nuts were used in the other. The following percentages of kernel for the varieties listed were computed after the nuts had been subjected to a relative humidity of 49 percent.

| Variety | Percent kernel |
|---|---|
| Cosford | 56.6 |
| Daviana | 55.7 |
| White Aveline | 53.1 |
| Red Aveline | 52.9 |
| Nottingham | 51.2 |
| Tertile de Coutard | 48.9 |
| DuChilly | 47.4 |
| Barcelona | 46.1 |
| Montebello | 40.5 |
| Merville de Bolwyller | 39.9 |
| Sicilian Seedlings (imported) | 34.6 |

## RATE OF CHANGES IN WATER CONTENT

The rate at which filberts gain or lose moisture has already received some attention (tables I, II, III), but to obtain more knowledge concerning this process, the following tests were undertaken:

**Rate of decrease in water content.** Specimens of Barcelona which had just been gathered and which contained about 22 percent water were arranged into a lot weighing 270.24 grams. These nuts were then subjected to living room humidities varying from about 49 percent to 55 percent. Weighings were made at the end of 48-hour periods, this work continuing for eighteen days, at the end of which no further loss of weight occurred. Table VII gives the data obtained.

TABLE VII. RATE OF DECREASE OF WATER CONTENT

| Date | Weight in grams | Loss in grams, 48-hour periods | Loss in percents, 48-hour periods |
|---|---|---|---|
| October 12 | 270.24 | -------- | ------ |
| October 14 | 253.21 | 17.03 | 6.3 |
| October 16 | 247.41 | 5.82 | 2.1 |
| October 18 | 243.21 | 4.20 | 1.6 |
| October 20 | 241.10 | 2.11 | .8 |
| October 22 | 239.52 | 1.58 | .6 |
| October 24 | 238.31 | 1.21 | .5 |
| October 26 | 237.20 | 1.11 | .4 |
| October 28 | 236.82 | .38 | .1 |
| October 30 | 236.82 | .00 | .0 |
| Total | --------- | 33.42 | 12.4 |

**Rate of increase in water content.** For this phase of the experiment, specimens of Barcelona were dried down in the Freas oven until the water content was reduced to 6.1 percent. These were then arranged into a lot weighing 176.01 grams, and were subjected to a relative humidity of 100 percent. Weighings as before were made at the end of 48-hour periods, continuing until such a time as the nuts had ceased to take on water, 28 days being required for this equilibrium to be reached. Table VIII gives the data obtained during this test.

From the data presented in tables VII and VIII and also in tables I, II and III, it appears that the rate at which filberts gain or lose moisture is dependent upon several factors. It is affected, in the first place, by relative humidity, the rate of gain being accelerated at increased humidities and retarded at decreasing humidities, while the converse of this is true for the rate of loss. It is influenced, in the second place, by the amount of water contained by the nuts themselves. This is shown by the fact that at constant humidities, the amount of water gained or lost diminishes as the state of equilibrium is approached. It is influenced, further, by temperature and also by air circulation. It is interesting to note in tables VII and VIII that comparatively green filberts lost 12.4 percent of their weight in 18 days while more or less dry filberts gained 18.2 in weight in 28 days. All conditions being equal, the rate of gain or loss of moisture is greater in the case of the kernels than in that of the shells. Kernels alone when subjected to a humidity of 100 percent gained 16.5 percent in weight in 12 days while shells gained but 7.3 percent. During the same period, kernels lost 5.5 percent of their weight at 0 percent humidity while shells lost 5.3 percent.

TABLE VIII. RATE OF INCREASE OF WATER CONTENT

| Date | Weight in grams | Loss in grams, 48-hour periods | Loss in percents, 48-hour periods |
|---|---|---|---|
| October 19 | 176.01 | -------- | ------ |
| October 21 | 187.50 | 11.49 | 6.5 |
| October 23 | 192.83 | 5.33 | 3.0 |
| October 25 | 196.30 | 3.47 | 1.9 |
| October 27 | 198.91 | 2.61 | 1.4 |
| October 29 | 199.82 | .91 | .5 |
| October 31 | 200.54 | .72 | .4 |
| November 2 | 202.12 | 1.58 | .9 |
| November 4 | 203.50 | 1.38 | .8 |
| November 6 | 204.85 | 1.35 | .7 |
| November 8 | 206.32 | 1.47 | .8 |
| November 10 | 207.44 | 1.12 | .6 |
| November 12 | 208.33 | .89 | .5 |
| November 14 | 209.21 | .88 | .5 |
| November 16 | 209.21 | .00 | .0 |
| Total | --------- | 33.20 | 18.2 |

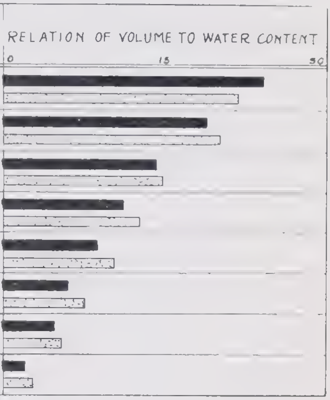
## EFFECTS OF MOISTURE ON THE TEXTURE AND QUALITY OF FILBERTS

The texture of filberts seems to be affected considerably by changes of the water content, being more or less soft when the water content is high and becoming hard and brittle as it diminishes. In fact, textures over a wide range of consistency can be obtained merely by varying the water content. With such nuts as the walnut and pecan, the texture remains at a rather constant degree of softness, regardless of moisture conditions. It was found that to be in good condition for eating, filberts should contain from 12 to 15 percent water, and that to maintain this level, the nuts must be kept for a time at a relative humidity of at least 80 percent. Filberts which have been dried and then allowed to regain their water content do not differ materially in texture and quality from nuts which have been kept constantly at high humidities. So long as the nuts are sweet and free from damage by decay organisms, they regain practically all of their original freshness when allowed to take on sufficient moisture. In fact, when the water content is allowed to go beyond 12 or 15 percent the nuts even regain the green flavor characteristic of newly gathered filberts.

## RELATION OF WATER CONTENT TO VOLUME

Observations in the preceding phases of these experiments showed that the volume of filberts varies with the water content; filberts which are losing moisture, for example, are also losing volume, while those which are increasing in moisture content are increasing in volume.

| LOT NUMBER | RELATIVE HUMIDITY | TOTAL VOLUME IN C. C. | VOLUME OF DRY MATTER IN C. C. | WATER CONTENT IN PERCENTS | INCREASE IN VOLUME |
|---|---|---|---|---|---|
| 1 | 100 | 285 | 225 | 24.2 | 21.8 |
| 2 | 85 | 288 | 252 | 17.8 | 19.4 |
| 3 | 75 | 260 | 222 | 14.2 | 14.6 |
| 4 | 60 | 260 | 228 | 10.8 | 12.3 |
| 5 | 49 | 265 | 238 | 8.4 | 10.2 |
| 6 | 40 | 248 | 230 | 5.7 | 7.3 |
| 7 | 35 | 224 | 212 | 4.6 | 5.5 |
| 8 | 0 | 232 | 226 | 1.9 | 2.5 |

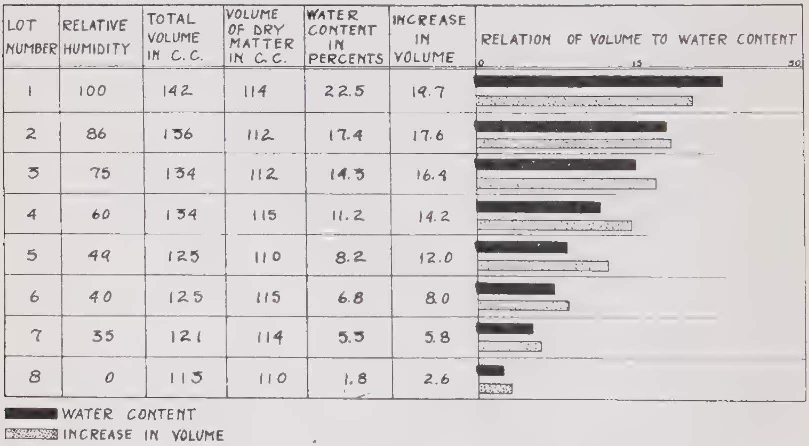


■ WATER CONTENT
▨ INCREASE IN VOLUME

Fig. 3. The relation of water content to the volume of Barcelona filberts.

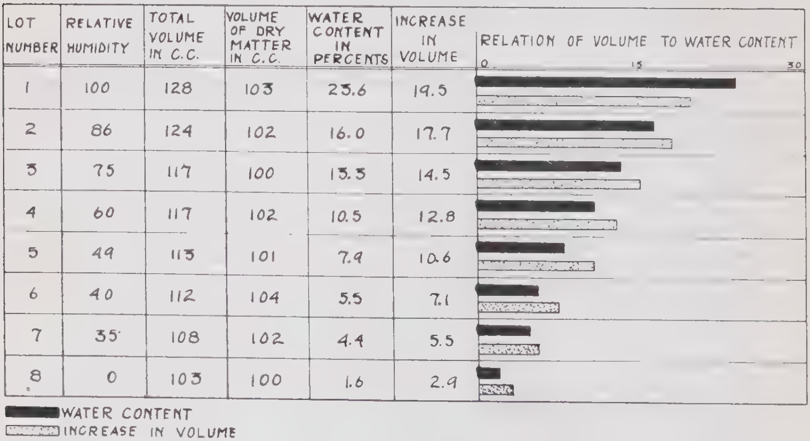
To find the amounts of gain or loss in volume, the following test was undertaken: Eight lots each of Barcelona, Du Chilly, and Nottingham were subjected to the relative humidities shown in figures 3, 4, and 5. The nuts were kept at these humidities until a state of equilibrium was reached, when no further gain or loss in weight took place. The volume of each lot was then ascertained by immersing the nuts in water and measuring the amounts of displacement. The lots were then dried down to complete dryness in the Freas oven and the volume was computed as before. The differences in volume, then, between the first and second determination of each lot could be assumed to represent the amount of the total volume attributable to the water content. Since the water content was known, in each case, it was a comparatively easy matter to compute the relation of water content to volume. Figures 3, 4, and 5 give the data obtained with the three varieties and show the water-volume relationship as computed.

Evidently every gain or loss in water content is accompanied by a corresponding gain or loss in volume, and in all cases except lot 1 of each variety, the gain or loss in volume slightly exceeds the gain or loss in moisture. For example, lot 2 of the Barcelona series held at a humidity of 86 percent was found to contain 17.8 percent water, and as computed this amount of moisture was responsible for 19.4 percent of the volume. Lot 4 of the same series retained 10.8 percent of water and this was responsible for 12.3 percent of the volume. Lot 1 of each variety seems to have been an exception to this rule. In the case of lot 1 of Barcelona, the water content was 24.2 percent and this seems to be responsible for only 21.8 percent of the volume. In the light of other phases of these experiments, however, this discrepancy, in part at least, can be accounted for. Referring back to the data on the "Water Content of Shells and Kernels" (Fig. 2), it is recalled that at high humidities the kernels take on a much higher percentage of moisture than do the shells. It is the shells and not the kernels, however, that determine the volume, so while the water content of the kernels figures in the total water content, it does not figure in the volume changes. When the moisture content of the shells alone is taken into account with Barcelona, held at 100 percent humidity, a water content of 21.3 percent is responsible for 21.8 percent of the volume.



| LOT NUMBER | RELATIVE HUMIDITY | TOTAL VOLUME IN C. C. | VOLUME OF DRY MATTER IN C. C. | WATER CONTENT IN PERCENTS | INCREASE IN VOLUME |
|---|---|---|---|---|---|
| 1 | 100 | 142 | 114 | 22.5 | 19.7 |
| 2 | 86 | 136 | 112 | 17.4 | 17.6 |
| 3 | 75 | 134 | 112 | 14.3 | 16.4 |
| 4 | 60 | 134 | 115 | 11.2 | 14.2 |
| 5 | 49 | 125 | 110 | 8.2 | 12.0 |
| 6 | 40 | 125 | 115 | 6.8 | 8.0 |
| 7 | 35 | 121 | 114 | 5.3 | 5.8 |
| 8 | 0 | 113 | 110 | 1.8 | 2.6 |

Fig. 4. The relation of water content to the volume of Du Chilly filberts.



| LOT NUMBER | RELATIVE HUMIDITY | TOTAL VOLUME IN C.C. | VOLUME OF DRY MATTER IN C.C. | WATER CONTENT IN PERCENTS | INCREASE IN VOLUME |
|---|---|---|---|---|---|
| 1 | 100 | 128 | 103 | 23.6 | 19.5 |
| 2 | 86 | 124 | 102 | 16.0 | 17.7 |
| 3 | 75 | 117 | 100 | 13.3 | 14.5 |
| 4 | 60 | 117 | 102 | 10.5 | 12.8 |
| 5 | 49 | 113 | 101 | 7.9 | 10.6 |
| 6 | 40 | 112 | 104 | 5.5 | 7.1 |
| 7 | 35 | 108 | 102 | 4.4 | 5.5 |
| 8 | 0 | 103 | 100 | 1.6 | 2.9 |

Fig. 5. The relation of water content to the volume of Nottingham filberts.

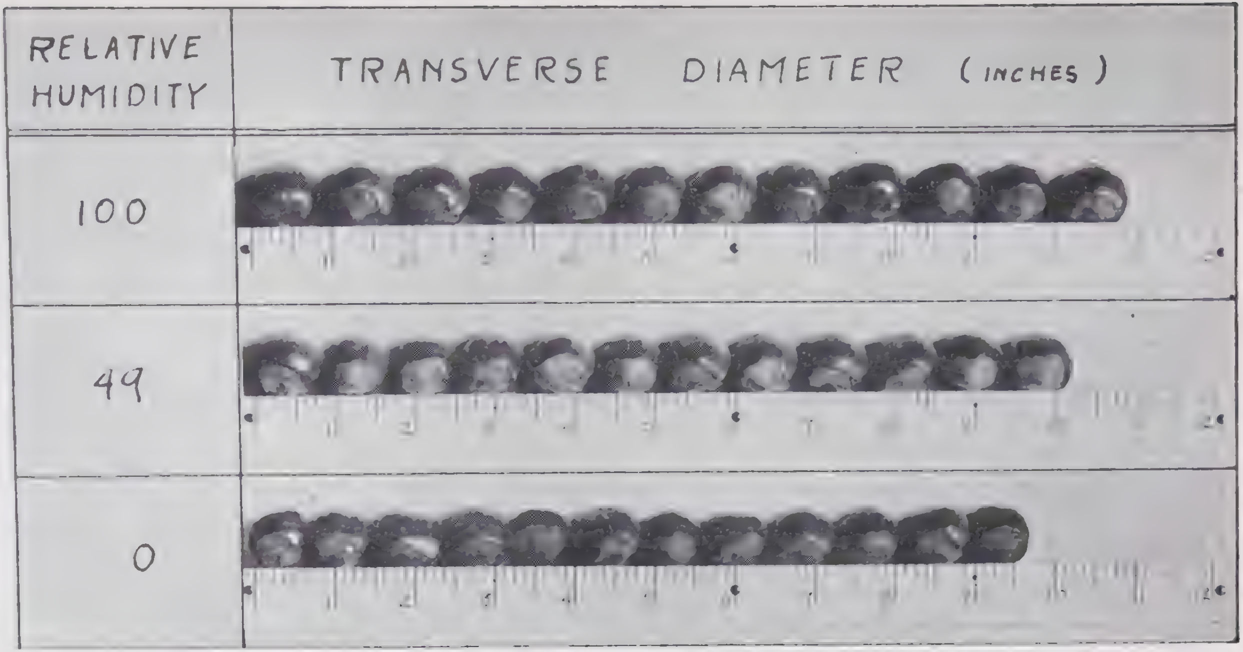


Fig. 6. The effects of humidity on the volume of filberts. The twelve specimens of Barcelona shown here were first subjected to a relative humidity of 49 percent. Picture 2 was taken following this treatment. They were then held at a relative humidity of 100 percent, wherein the volume increased as shown in picture 1. Following this they were exposed to a relative humidity of 0 percent wherein they lost volume as indicated by picture 3.

## HUMIDITY IN RELATION TO DEVELOPMENT OF DECAY ORGANISMS

Filberts are susceptible to the attack of decay organisms, chief among which are molds of various species. Imported filberts as found in American markets frequently show the effects of mold, in many cases the quality being so impaired as to render the nuts practically worthless. Even the odor of mold is sufficient to give filberts a bad taste. Mold usually develops only in high humidities accompanied by fairly high temperatures. In the present experiments, mold invariably developed in relative humidities of above 80 percent and a temperature of 20° C. Filberts seem to be especially susceptible to species of Rhisopus, Penicillium, and Botrytis. Mold develops rapidly in the field during the warm rains of early fall when filberts are falling to the ground; consequently the nuts often mold before harvesting or may become contaminated with mold spores only to become moldy in storage if conditions are favorable for these organisms to grow. Mold apparently penetrates the shells of filberts very quickly, the kernels often showing signs of infection even though the nuts have lain on the ground only a short time. Nuts which had been thoroughly sterilized on the outside developed internal infection in a few days when subjected to high humidities. Filberts of the non-husking types such as the Du Chilly and Daviana are much more susceptible to infection in the field than are the self-husking sorts such as Barcelona. Green nuts left in piles or stored at high humidities with insufficient ventilation are very apt to become moldy.

## WRAPPING MEDIUMS IN RELATION TO LOSS OF MOISTURE

It has long been known that certain mediums tend to retard evaporation and thus reduce loss of moisture. Paraffin wrappers, for example, reduce the loss of moisture from bread, while tinfoil and similar materials reduce evaporation from candies and chewing gum. The following test was undertaken with the aim of finding some wrapping medium which could be used in the trade to preserve the freshness of filberts for a longer period than is possible under present methods of handling.

Filberts which contained about 17.5 percent water were arranged into 150 c.c. beakers. These in turn were covered with various materials, including celloidin, common wood pulp wrapping paper, commmercial wax paper, and heavily coated paraffin paper. The beakers were carefully sealed with wax so as to make sure that the only means of escape for the moisture was through the medium itself. One beaker was left uncovered for a check. All the beakers were then placed over pure sulfuric acid, weighings being made daily for a period of 12 days. The complete data from these weighings are given in Table IX.

The results obtained in this test show that loss of moisture is influenced more or less by the use of various wrapping mediums. Through heavily coated paraffin paper, for example, the nuts lost only 3.2 percent of their weight in 12 days, while during the same period those of the uncovered check lost 8.3 percent of their weight. Common wrapping paper and celloidin do not seem to be very effective in preventing loss of moisture, the filberts losing 7.6 percent and 7.5 percent of their weight during the period. Over the same period, commercial waxed paper proved only slightly more efficient, permitting loss of 5.8 percent of weight.

TABLE IX. EFFECT OF VARIOUS WRAPPERS ON LOSS OF WATER IN FILBERTS

| Lot number | Materials | Weight Nov. 21 | Weight Nov. 22 | Weight Nov. 23 | Weight Nov. 24 | Weight Nov. 25 | Weight Nov. 26 | Weight Nov. 27 | Weight Nov. 28 | Weight Nov. 29 | Weight Nov. 30 | Weight Dec. 1 | Weight Dec. 2 | Loss of water in percents |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 71.15 | 69.95 | 69.12 | 68.49 | 67.65 | 67.34 | 66.89 | 66.44 | 66.04 | 65.73 | 65.48 | 65.12 | 8.3 |
| 2 | Common wrapping paper | 80.56 | 79.20 | 78.34 | 77.70 | 76.93 | 76.57 | 76.12 | 75.68 | 75.21 | 74.88 | 74.66 | 74.47 | 7.6 |
| 3 | Celloidin | 75.14 | 74.00 | 73.27 | 72.62 | 71.93 | 71.59 | 71.15 | 70.74 | 70.30 | 70.00 | 69.75 | 69.47 | 7.5 |
| 4 | Commercial wax paper | 74.76 | 74.13 | 73.60 | 73.21 | 72.79 | 72.37 | 72.00 | 71.71 | 71.35 | 71.10 | 70.75 | 70.44 | 5.8 |
| 5 | Paraffin coated paper | 74.29 | 73.69 | 73.50 | 73.29 | 73.07 | 72.95 | 72.75 | 72.60 | 72.40 | 72.28 | 72.15 | 72.04 | 3.2 |

## PRACTICAL APPLICATION

The possible bearing of conclusions reached in these experiments upon handling practices has already been suggested, but to bring out the practical side more clearly, it is perhaps best to treat it under a separate heading.

**Gather and dry as soon as possible.** Since filberts are apt to become moldy in the field, they should be gathered as soon as possible after falling to the ground. Even though they do not mold at the time, they may become contaminated with mold spores which may give trouble later on. Immediately after gathering, the nuts should be dried somewhat so that they will be safe. Green filberts become moldy in a short time if kept in large piles or places where air circulation is poor. Natural drying under living room conditions seems to be very satisfactory. Excessive drying is not necessary, and besides, this practice results in needless loss of weight and volume and also causes the texture of the kernels to become hard and brittle. Moreover, there is but little gained by drying filberts excessively and then storing them in places where they will regain the moisture lost. There is no indication that artificial drying improves the quality of filberts.

**Inadvisable to store in fresh condition.** It does not seem advisable to try to keep filberts fresh during the entire period of storage. This would require constant storage at a relative humidity of about 80 percent. Such a humidity would be difficult to maintain under the conditions prevailing in the trade; and besides, there is danger of mold at such humidities, slight reductions in temperature being apt to cause condensation sufficient to foster the growth of mold spores. Seemingly, it is best to allow the nuts to dry down to a safe water content, permitting them to regain their moisture only when they are about to be consumed. In England, filberts are sometimes kept in a fresh condition by storing in moist sand or salt. This method, however, would be unsatisfactory here in that nuts cannot be conveniently shipped under such conditions and that they are in constant danger from decay organisms.

**Moisture in relation to texture and quality.** Many people discriminate against the filbert because its texture often becomes hard and brittle shortly after harvest. When kept in living rooms or in store bins, fresh filberts may lose enough moisture in three or four days to be unpalatable to many consumers. Since filberts can be made to gain or lose moisture, however, nuts to satisfy all tastes can be secured at any time with but little difficulty.

Two general methods for refreshing filberts were found to be effective. Soaking in water for 6 to 8 hours and then allowing to dry down to the right consistency, proved fairly satisfactory. No evil effects resulted from this practice, apparently, so long as the nuts were not soaked too long and were allowed to dry off quickly after immersion. The second method found effective consists in subjecting the nuts to high humidities and causing them to absorb moisture from the air. This method is naturally much slower than the former but a product of uniform texture and moisture content can be obtained by its use. Humidifiers may be constructed in various ways. For the use of growers, a fairly air-tight pit under ground, where the floor can be kept covered with water, will give sufficient moisture in most cases. False floors should be used so that the nuts will not come in direct contact with the water. Nuts treated in this way should be removed from the pit as soon as they have regained their proper texture. For use in the home or retail establishment, a humidifier of the type shown in Fig. 7 is satisfactory. This can be made from regular glass desiccators, candy jars, goldfish bowls, or any container which is more or less air-tight. A wire basket of some kind should be provided to keep the nuts up out of the water and permit circulation of air. Very satisfactory results were obtained by using a saturated solution of common salt in the humidifier instead of pure water, such a solution giving a relative humidity of about 80 percent over a fairly wide range of temperature. This has advantage over pure water in that filberts can be kept almost indefinitely at this humidity without becoming too moist or soggy. Again, there is but little danger of mold when salt solution is used because over such a solution temperature changes are not apt to cause condensation. A saturated salt solution can be obtained by dissolving 3½ pounds of common salt in a gallon of water. The sediment or undissolved salt should be put in the humidifier along with the liquid to make sure that a saturated solution has been obtained.

When pure water is used in the humidifiers, unshelled filberts should regain sufficient moisture in 5 to 7 days. Considerably more time is required when salt solution is used. Shelled filberts over pure water usually regain sufficient moisture in 8 to 12 hours.

**Effect of moisture on cracking quality.** In the case of dry filberts it is usually difficult to remove the shells without injury to the kernels. The kernels invariably are brittle and a considerable percentage of them are damaged by the cracking operation. It was found, however, that much of this trouble can be eliminated by soaking the nuts for a time before cracking. When the kernels are soft they do not break so readily and the cracking quality of the nuts is thereby much improved.

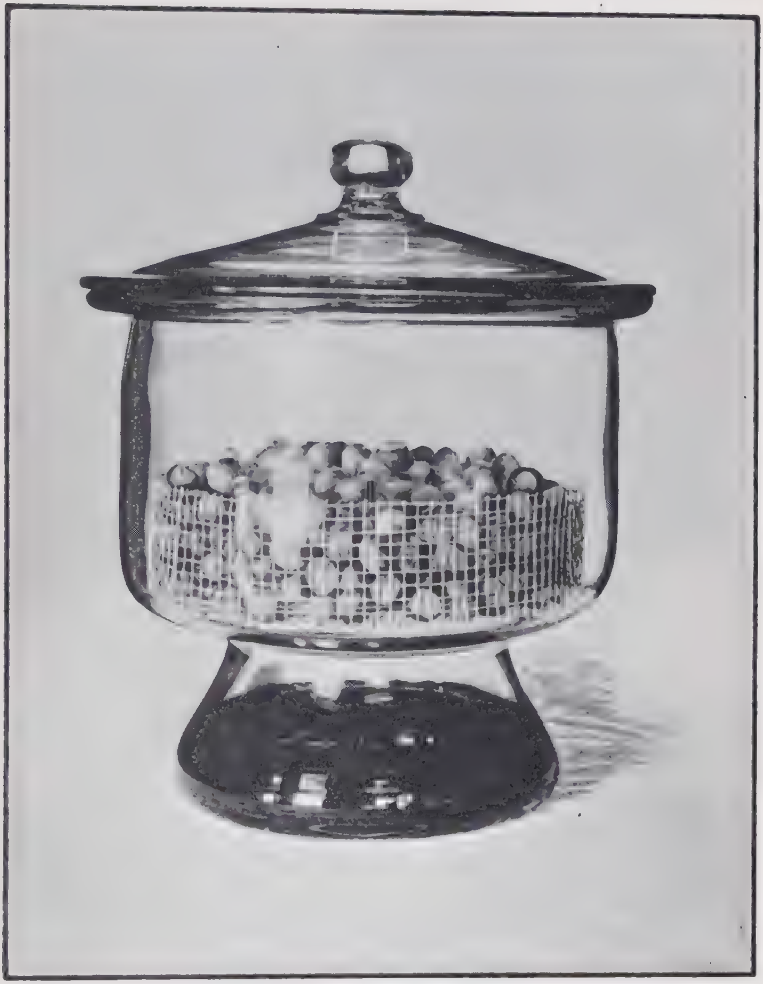


Fig. 7. A satisfactory type of humidifier for use in refreshing filberts.

**Moisture changes in relation to weight.** The gain or loss of moisture by filberts even within the range of common relative humidities is sufficient to affect the weight of the nuts. Filberts kept in a damp cellar, for example, at a possible humidity of 85 percent may weigh from 8 to 12 percent more than the same filberts kept in the bins of a grocery store in summer when the relative humidity may be as low as 40 to 50 percent. Not only the grower but also the dealer and consumer of filberts should be familiar with the action of humidity upon the weight of these nuts.

**Volume changes.** The volume changes which may occur in filberts are sufficient to have some bearing upon the matter of standards and grades. The volume of green Barcelonas, for example, would be from 10 to 12 percent greater than the volume of the same nuts kept for a time at a relative humidity of 40 to 50 percent. Nuts dried down to 6 percent water would gain 7 to 8 percent in volume if brought back to a water content of from 12 to 15 percent. Obviously it would make considerable difference whether nuts were graded while green or while dried.

**Use of wrapping mediums.** Of the various wrapping mediums tested, heavily coated paraffin paper gave the best results. Such paper was instrumental in reducing the rate of moisture loss to about one-third that taking place in the open or in common paper sacks. Paraffin paper sacks would do much to prolong the freshness of filberts after they are in the hands of the consumer. Seemingly, air-tight jars or sealed cans are not satisfactory. Nuts placed in such containers for any length of time become stale and lose their characteristic flavor.

## ACKNOWLEDGMENT

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## CONCLUSIONS

1. Humidity has a definite bearing upon the water content and weight of filberts. The water content of these nuts increases or decreases with the relative humidity of the air in which they are kept. Over the range of humidities employed in these experiments, the water content of unshelled Barcelona nuts varied from 1.9 to 24.2 percent, that of Du Chilly from 1.8 to 22.5 percent, and that of Nottingham from 1.6 to 23.6 percent. Even within the scope of common relative humidities, the water content and weight of filberts vary enough to have bearing upon handling practices.

2. The previous moisture condition of filberts, apparently, has but little to do with their present or future capacity to gain or lose moisture. Nuts which have been dried down to complete dryness take on practically as much water at high humidities as those which are only partly dried.

3. At ordinary humidities, water in considerable amounts is contained by both the shells and the kernels of filberts. Both apparently gain or lose water in accordance with the relative humidities to which they are subjected. The ratio, however, does not remain constant throughout the range of humidities. At 100 percent relative humidity, for example, kernels of Barcelona took on 27.2 percent water while shells took on only 21.3 percent. At 60 percent relative humidity, the kernels contained only 6.0 percent water while the shells contained 12.9 percent. At 0 percent relative humidity, the kernels retained 2.2 percent water while the shells retained but 0.9 percent.

4. Since the ratio of the water content of shells and kernels is not constant throughout the range of humidities, to obtain a fair comparison of the percentage of shell and kernel of the different varieties, it is necessary that the specimens used in computing the percentages be of the same water content.

5. The rate at which filberts gain or lose moisture is dependent upon (1) relative humidity, (2) water content, (3) temperature, and (4) aeration. All conditions being equal, the rate of gain or loss is greater in the case of the kernels than in that of the shells.

6. The texture of filberts seems to be affected considerably by changes of the water content, being more or less soft when the water content is high and becoming hard and brittle as it diminishes. To be in good condition for eating, filberts should contain from 12 to 15 percent water. To maintain or acquire this amount of moisture, the nuts must be subjected to a relative humidity of at least 80 percent. Nuts that have been dried and then allowed to regain their water content do not differ materially in texture and quality from nuts which have been kept moist from the beginning. The water content of filberts may be increased in actual practice by immersion in water or by the use of humidifiers.

7. When the moisture content of filberts is high, their cracking quality is much better than when they are comparatively dry.

8. The volume of filberts varies in direct proportion to their water content. Every gain or loss in moisture is apparently accompanied by a gain or loss in volume, and in most cases the gain or loss in volume slightly exceeds the gain or loss in moisture. Volume changes occasioned by moisture changes are sufficient to have bearing upon the matter of grades and standards.

9. Filberts are susceptible to the attack of decay organisms, chief among which are certain species of mold. These usually develop in the presence of high humidities and fairly high temperatures. Filberts frequently mold in the field or become contaminated, so that they become moldy after harvesting, and consequently they should be gathered from the ground as soon as possible.

10. To be free from danger of mold, filberts should be dried down so that their water content is below 12 percent. It does not seem advisable to attempt to keep filberts in a fresh condition during the entire period of storage. It is best, seemingly, to allow them to dry down to a safe

water content, permitting them to regain their moisture only when about to be consumed. Excessive drying of filberts is not necessary or desirable. Natural drying under living room conditions seems satisfactory.

11. The loss of moisture in filberts may be retarded more or less by the use of certain wrapping mediums. Through heavily coated paraffin paper, the rate of loss of moisture was reduced to about one-third that of filberts left uncovered. Common wood pulp wrapping papers, commercial wax papers and celloidin did not prove effective in preventing loss of moisture. Air-tight containers, seemingly, are undesirable in the handling of filberts.

Station Bulletin 203 May, 1924

Oregon Agricultural College

Experiment Station

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By

ALBERT E. ENGBRETSON and GEORGE R. HYSLOP

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# SUMMARY

Dairying is the main agricultural industry of the Coast largely because of favorable climatic conditions, distance to market, and inability to use large areas of land except by pasturing.

Maintenance of a high plane of dairy production requires more legume hay, better pastures, and more succulent crops for winter feeding and to supplement summer pasture.

Choice of forage crop depends partly on the climate of the section of the Coast under consideration, whether it is to be grown on hill, bottom, or tide-land, and what manures or fertilizers may be economically applied at that place. Soil fertility is an important problem, and the use of fertilizer or manure depends on the soil type and the crop grown.

Census figures show great variability in kind of crop and in yield per acre in the Coast counties, but they show a general shortage of legume hay and in some sections a shortage of succulents.

Forage production to meet real Coast needs must provide more legumes for hay, silage, and summer succulents. Successful inoculation, lime, manure, and early planting give best results with legumes.

Common, Hungarian, and woolly podded vetches for fall sowing, and purple and common vetches for spring planting, are the best vetches. They should be sowed with oats.

Peas and oats spring planted are probably the best annual legume combination for the Coast.

Red and Alsike clover are excellent hay crops for newly cleared upland and bottom soils, and where lime and manure are available their production may be profitably continued on all well-drained soil types.

Of the grains for hay, Gray winter oats is probably best when fall sown alone or as a supporting crop for vetch.

Turnips, rutabagas, and mangels are all important—turnips for summer feeding, and rutabagas and mangels for winter use.

Mangels are grown where early planting is necessary and where the root maggot injury to rutabagas and turnips is severe.

Root crops respond to heavy applications of manure (20 tons or more an acre) and superphosphate (400 to 500 pounds an acre).

Mangels must be lifted and stored for winter feeding, while rutabagas may be fed direct from the field.

Standard root varieties are Pomeranian White Globe turnips, Improved American and Skirvings' Improved rutabagas, and Prizewinner, Mammoth Long Red, and Giant Intermediate mangels.

Green feed or soiling crops are necessary to supplement summer pasture. They produce large yields of forage on small acreages where intensive production is practiced.

Three times as much silage is grown in the south as in the north Coast section. Corn, peas-and-oats, and vetch-and-oats are used. Peas-and-oats is the best silage combination where it is too cool for corn.

Pasture improvement through new seeding and proper management will produce much new cheap forage.

# Forage Crops for Oregon Coast Counties

By

Albert E. Engbretson and George R. Hyslop

## CONDITIONS SIMILAR IN CLATSOP, TILLAMOOK, AND LINCOLN COUNTIES

The facts, suggestions, and recommendations presented in this bulletin are intended for the Oregon Coast counties and the more moist sections of Columbia county. The importance and need of the dairy industry and other conditions influencing the selection and production of forage crops are near enough alike in Clatsop, Tillamook, and Lincoln and the more moist areas of Colmbia counties that the crops and practices recommended should apply with but slight modification. In Coos, Curry, west Lane, and west Douglas counties the soil and climatic conditions vary sufficiently from those of Clatsop county that the crops and practices recommended will apply only in part. The longer growing season and lighter rainfall in some sections of these southern counties offer possibilities for other crops such as barley and corn.

**Dairying the main agricultural industry.** Dairying is the outstanding agricultural industry of Oregon Coast counties. The moist, mild climate and long growing season are unusually favorable for abundant rich pastures. The mild climate and long season on good pasture likewise are unusually favorable to the dairy cow and to establishing a successful dairy industry. Dairy products valued at $4,549,279.00 were produced in the six counties named in 1919, according to the 1920 Federal census. For the same year the number of cows is given as 53,612 valued at $4,064,942.00. Table I gives distribution by counties.

TABLE I. DAIRY CATTLE AND DAIRY PRODUCTS, 1920 CENSUS

| County | Number of dairy cattle | Value of dairy cattle | Value of dairy products |
|---|---|---|---|
| Clatsop | 5,476 | $ 417,691 | $ 400,728 |
| Columbia | 7,718 | 617,257 | 543,332 |
| Tillamook | 14,390 | 1,354,406 | 1,765,906 |
| Lincoln | 5,768 | 287,782 | 255,411 |
| Coos | 16,155 | 1,108,291 | 1,289,775 |
| Curry | 4,105 | 279,515 | 294,127 |
| Totals | 53,612 | $4,064,942 | $4,549,279 |

## MAINTAINING THE DAIRY INDUSTRY

**Dairying needs more legume hay.** Liberal feeding of good legume hay is essential to high average production. As the percentage of hay that is legume increases, production increases and cost of production decreases, other things being equal. A good producing cow requires from two to three pounds daily of digestible protein to maintain production. Besides furnishing a desirable cheap protein, legume hay carries a large amount of minerals essential to health and maintenance. If the protein is withheld there is a marked decrease in milk production. If it is purchased in the form of high protein concentrates the cost is greater than in the form of legume hay, and profits are correspondingly less.

An analysis of the United States Census figures for 1919 for the hay, green forage, silage, root, and feed grain production of each of the Coast counties is shown in tables II, III, and IV. These census figures show a total production of 32,689 tons of legume hay for the Coast counties in 1919. The number of dairy cows is given as 53,612. The average yield of legume hay as given is 2.4 tons per acre. The average yield without lime or manure at the Astoria Experiment Station is about two to two and one-half tons. When lime and manure are applied the average yield is three and one-half tons. Since these yields of legume hay can be grown on the average dairy farm of the Coast counties, it would seem that the dairy industry would profit by increasing production of legume hay to at least one ton per head.

**Crops for succulence are important.** The aim of every successful dairyman is to try to maintain conditions as they are in the spring of the year. Production is then at its highest due to an abundance of pasture which furnishes ample green feed for production, acts as a tonic, creates a keen appetite, and is a cheap source of feed. Succulent feeds such as soiling crops, silage, and roots furnish the same things but not to the same extent. Succulent feeds for the entire year are becoming more essential every year due to necessity of maintaining production at a high level. With hay and grain this can not be done economically. During years of low summer rainfall on land having a limited pasture season, or on farms carrying the maximum number of producing cows, the use of soiling crops during summer becomes necessary. There are few sections of the country where it is as easy to provide an ample supply of succulence with or without the use of a silo. On farms where fifteen or more cows are fed during the winter a silo will prove a good investment.

TABLE II. ACREAGE AND PRODUCTION OF HAY FROM PERENNIAL GRASSES AND LEGUMES BY COUNTIES AND DISTRICTS FOR THE COAST SECTION

| | Timothy | | Timothy and clover mixed | | Clover alone | | Alfalfa | | Other tame or cultivated grasses | | All tame or cultivated grasses | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *acres* | *tons* | *acres* | *tons* | *acres* | *tons* | *acres* | *tons* | *acres* | *tons* | *acres* | *tons* |
| Clatsop | 80 | 132 | 2154 | 5453 | 199 | 405 | 13 | 40 | 848 | 1839 | 3294 | 7869 |
| Columbia | 353 | 769 | 3149 | 7274 | 942 | 2263 | 101 | 336 | 1496 | 3314 | 6041 | 13956 |
| Lincoln | 212 | 424 | 1288 | 2454 | 447 | 868 | 11 | 26 | 2204 | 3522 | 4162 | 7294 |
| Tillamook | 36 | 83 | 1153 | 3180 | 113 | 263 | 32 | 36 | 6231 | 12359 | 7565 | 15921 |
| North Coast total | 681 | 1408 | 7744 | 18361 | 1701 | 3799 | 157 | 438 | 10779 | 21034 | 21062 | 45040 |
| Coos | 48 | 29 | 1262 | 3173 | 1124 | 2914 | 35 | 74 | 3665 | 8784 | 6134 | 14974 |
| Curry | 1 | 1 | 25 | 51 | 437 | 1121 | 95 | 280 | 1523 | 3214 | 2081 | 4667 |
| South Coast total | 49 | 30 | 1287 | 3224 | 1561 | 4035 | 130 | 354 | 5188 | 11998 | 8215 | 19641 |
| Coast total | 730 | 1438 | 9031 | 21585 | 3262 | 7834 | 287 | 792 | 15967 | 33032 | 29277 | 64681 |

TABLE III. ACREAGE AND PRODUCTION OF HAY FROM WILD GRASS, SMALL GRAIN, AND ANNUAL LEGUMES AND OF SILAGE, GREEN FORAGE, AND ROOT CROPS, BY COUNTIES AND DISTRICTS FOR THE COAST SECTION

| | Wild salt or prairie grass | | Small grains cut for hay | | Annual legumes cut for hay | | Silage crops | | Corn cut for forage | | Kafir sorghum, etc., for forage | | Root crops for forage | | Hay and forage total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *acres* | *tons* | *acres* | *tons* | *acres* | *tons* | *acres* | *tons* | *acres* | *tons* | *acres* | *tons* | *acres* | *tons* | *acres* | *tons* |
| Clatsop | 423 | 781 | 768 | 1642 | 150 | 403 | 46 | 356 | ....... | ....... | 2 | 6 | 180 | 4665 | 4863 | 15722 |
| Columbia | 2250 | 2631 | 2031 | 3999 | 165 | 472 | 546 | 4304 | 111 | 605 | 31 | 323 | 228 | 2281 | 11403 | 28571 |
| Lincoln | 476 | 709 | 3274 | 5912 | 182 | 334 | 216 | 1186 | 91 | 322 | 15 | 45 | 285 | 4317 | 8701 | 20119 |
| Tillamook | 882 | 1772 | 2050 | 4738 | 151 | 68 | 185 | 1330 | 12 | 76 | ....... | ....... | 149 | 2356 | 10994 | 26261 |
| North Coast total | 4031 | 5893 | 8123 | 16291 | 648 | 1277 | 993 | 7176 | 214 | 1003 | 48 | 374 | 842 | 13619 | 35961 | 90673 |
| Coos | 131 | 261 | 6020 | 14967 | 342 | 1068 | 2543 | 22120 | 437 | 2546 | 9 | 26 | 539 | 13937 | 16155 | 69899 |
| Curry | 87 | 133 | 2011 | 4715 | 37 | 133 | 142 | 1315 | 189 | 1024 | ....... | 1 | 82 | 1780 | 4629 | 13768 |
| South Coast total | 218 | 394 | 8031 | 19682 | 379 | 1201 | 2685 | 23435 | 626 | 3570 | 9 | 27 | 621 | 15717 | 20784 | 83667 |
| Coast total | 4249 | 6287 | 16154 | 35973 | 1027 | 2478 | 3678 | 30611 | 840 | 4573 | 57 | 401 | 1463 | 29336 | 56745 | 174340 |

TABLE IV. ACREAGE AND PRODUCTION OF FEED GRAINS BY COUNTIES AND DISTRICTS FOR THE COAST SECTION

| | Corn | | Wheat | | Oats | | Barley | | Rye | | Mixed grains | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *acres* | *bu.* | *acres* | *bu.* | *acres* | *bu.* | *acres* | *bu.* | *acres* | *bu.* | *acres* | *bu.* | *acres* | *bu.* |
| Clatsop | 2 | 83 | 81 | 2818 | 534 | 25925 | 7 | 200 | -------- | -------- | -------- | -------- | 624 | 29026 |
| Columbia | 3 | 80 | 1315 | 33003 | 2314 | 107988 | 176 | 6194 | 52 | 1277 | 86 | 2916 | 3946 | 151458 |
| Lincoln | 36 | 1115 | 444 | 6331 | 963 | 35643 | 11 | 235 | 31 | 345 | 4 | 67 | 1489 | 43736 |
| Tillamook | None | | None | | None | | None | | None | | None | | None | |
| North Coast total | 41 | 1278 | 1840<br>mainly Columbia | 42152 | 3811 | 169556 | 194 | 6629 | 83 | 1622 | 90 | 2983 | 6059 | 224220 |
| Coos | 293 | 10775 | 184 | 4277 | 470 | 20890 | 556 | 31262 | 11 | 266 | 22 | 325 | 1536 | 67795 |
| Curry | 74 | 2398 | 30 | 444 | 112 | 4744 | 62 | 2299 | 3 | 12 | -------- | -------- | 281 | 9897 |
| South Coast total | 367 | 13173 | 214 | 4721 | 582 | 25634 | 618 | 33561 | 14 | 278 | 22 | 325 | 1817 | 77692 |
| Coast total | 408 | 14451 | 2054 | 46873 | 4393 | 195190 | 812 | 40190 | 97 | 1900 | 112 | 3308 | 7876 | 301912 |

According to the 1920 census figures, 64,921 tons of silage and roots were produced in the Coast counties to feed 53,612 dairy cows, or 1.21 tons per head. Because of the difficulty of curing hay the dairy ration should contain a large amount of succulence. Experience at the Astoria Station shows that at least two and a half tons of succulence per cow should be fed during the winter, October 15 to April 15. This amount can profitably be increased to four tons for each producing cow.

**Pasture maintenance vital.** Most of the dairy products of the Coast counties of Oregon are produced while the cows are on pasture. In Clatsop county approximately 61 percent is produced during the pasture months and 39 percent during late fall and winter months, part of this being produced from pasturage. The pasturage months are the most profitable as there is very little cash outlay for feed. In view of these facts the importance of pasturage can not be over estimated. It is generally true that after once established very little care is given pastures to maintain them or to increase their production. It is not a general practice to rotate pastures or to reseed when they begin to run out. Much of the pasture land is in such shape that it is impossible to do any pasture improvement other than reseeding until it has been leveled and cleared. The first step in pasture improvement is to put the land in such condition that it can be handled when there is need.

## SOIL AND CLIMATE IMPORTANT IN SELECTING FORAGE CROPS

For the purpose of this bulletin, hill land, bottom-land, and tide-land soil types are considered, and only limiting factors of climate are important here.

**Hill land.** The hill land has not been held in high favor due to low fertility when cleared but this class of land must be looked to for expansion of the dairy industry in the future.

Most of the hill land originally is timbered. It is gently sloping to rolling or steep; compared with tide-land, it is low in fertility when first cleared. The upland soil is easy to work and responds readily to fertilizers. With proper cropping and fertilizers for four or five years it will produce as much of any forage crops except pasture as tide-land or bottom-land. The necessary improvement and maintenance of fertility can be managed without difficulty on a dairy farm by proper care and use of manure.

**Tide-land.** The tide-land is level but is cut up by sloughs, and contains more or less logs and roots. It is rather difficult to put in shape for cultivated crops. The soil contains a large amount of organic matter and produces an abundance of grasses and clovers after the land has been slashed and burned. This production continues as long as there is an abundance of organic matter. For pasture the high production will continue perhaps ten or fifteen or more years and then the clover thins out and the pasture is not so good. Cultivated crops remove the organic matter more rapidly. In about eight or ten years the crop production is considerably reduced unless soil fertility is improved. The problem then is much the same as for the upland.

The tide-land soil is naturally best suited to pasture but if well drained and cultivated it will produce good yields of a variety of forage crops.

**Bottom-land.** The bottom-land occurs along streams and is subject to overflow. It has a greater and more lasting fertility than either the tide-land or the hill land. All forage crops suited to the Coast section grow well on the bottom-land. The soil structure, fertility, and abundant moisture are favorable to the finest of pasture. White clover and the better pasture grasses grow in abundance. This land, like all others, has its limits, however, and there is a problem of pasture maintenance, especially where the lands are not subject to periodical overflow.

**Soil fertility an important problem.** For the Coast section soil fertility is perhaps the most important factor in determining yield and quality of forage. Fertility becomes a problem sooner or later on each class of land. On the upland it is an immediate problem when the land is cleared. The tide-land and bottom-land are most productive when first reclaimed and the need of fertilizers comes later.

No other fertilizer has proved as valuable as barnyard manure. On the dairy farm proper care of the manure to prevent leaching, and its wise use on the land, will go a long way toward building and keeping up soil fertility and insuring good yields of forage with a minimum of weeds. Concrete gutters, bedding, and manure pits should be found on every modern dairy farm as the first essentials in maintaining fertility and satisfactory crop yields.

Certain commercial fertilizers are valuable to supplement manure for most profitable yields of some crops. Fertilizers for each crop are recommended in the crop discussions.

**Climatic factors.** The climate of the Coast counties is characterized by high annual rainfall; long, cool growing season; and mild winters. The precipitation varies from about sixty inches to over one hundred inches annually.

The heavy winter rains are a factor in reducing soil fertility especially of hill lands. For the period July 1 to September 1 the lack of rain in some years causes a shortage of pasturage and reduction in milk production. Accurate data for three years at the Astoria Station show that spring-freshened cows decreased in milk production 25.8 percent during this period.

Winter temperatures rarely drop below 20 degrees F. A light frost, however, causes the hill land to heave and in years of continued freezing and thawing even the hardy vetches winter-kill. This difficulty is slightly less on the tide-land and bottom-land. This factor is not a serious one but influences the selection of the crop and the cropping practices. Limited tests indicate that drilling to a depth of two inches rather than broadcasting may largely overcome the difficulty.

**Recommendations are based upon experiments and experience.** The growing need for more information on these and other problems was in mind when the John Jacob Astor Branch Agricultural Experiment* Station was established near Astoria, in Clatsop county, Oregon. This station is provided with about forty-five acres of typical tide-land and about ten acres of average hill land soil. This land was set aside for experimental work in 1913. Clearing and improvements were begun that year. Experiments with crops and soils were started in 1914 and have been continued and expanded as new land could be cleared and put in shape for cultivation. A dairy herd of fifteen to thirty head has been maintained since 1914.

The crops and practices recommended in the following pages are the result of experiments at the Experiment Station and observations of needs and practices on farms under similar conditions. They have been used successfully in providing for the station dairy herd, and most of the recommendations have been tried with good results by at least a few dairy farmers. It is believed that more dairy farmers could profit by adjusting their farming practices along the lines recommended.

## COAST CROP PRODUCTION SHOWN BY CENSUS FIGURES

United States census statistics for the year 1919 show clearly the forage cropping practices of the Coast sections. For convenience the Coast has been divided into the north and south group of counties. The north includes Clatsop, Columbia, Lincoln, and Tillamook. Columbia county has much land resembling Coast conditions as well as a large interior area where grain is grown. The south group includes Coos and Curry counties. Since the statistics for the Coast sections of Lane and Douglas counties cannot be segregated, they are omitted entirely. Table V gives the crop production by these groups.

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*The John Jacob Astor Branch Experiment Station was established by Act of the Legislature in 1913 (Chapter 228, Oregon Laws, 1913) for the purpose of investigating and demonstrating the agricultural possibilities of reclaimed swamp and logged-off lands. In accordance with a provision of the Act, Clatsop county provided approximately seventy acres of land and the necessary buildings, improvements, and initial equipment. The land acreage was later reduced to the present area of about 55 acres. From time to time Clatsop county has contributed additional assistance toward clearing and improvements. The Act establishing the station provides an annual state appropriation of $3000 for maintenance and operation, and places the station under the control and management of the Board of Regents of the State Agricultural College. The tide-land was diked in 1913, and since that time slashing, clearing, leveling, and improving both the tide-land and the hill land has involved so much time and expense that it has retarded experimental work. The crops now grown annually on both hill land and tide-land stand as a convincing demonstration of the value of these lands.

Part of the data on vetches and grasses reported herein were secured at the Astoria Station in cooperation with the Office of Forage Investigations of the United States Department of Agriculture.

TABLE V. ANALYSIS OF OREGON COAST CROPPING PRACTICES BASED ON U. S. CENSUS OF 1919

North counties—Clatsop, Columbia, Lincoln, Tillamook.
South counties—Coos, Curry.
West Lane and Douglas omitted because of inability to segregate Coast data from county statistics.

| Crop | North Coast | | South Coast | | Total | |
|---|---|---|---|---|---|---|
| | *acres* | *tons* | *acres* | *tons* | *acres* | *tons* |
| Annual legumes cut for hay | 648 | 1277 | 379 | 1201 | 1027 | 2478 |
| Timothy and clover | 7744 | 18361 | 1287 | 3224 | 9031 | 21585 |
| Clover alone | 1701 | 3799 | 1561 | 4035 | 3262 | 7834 |
| Alfalfa | 157 | 438 | 130 | 354 | 287 | 792 |
| Total legume and legume and timothy | 10250 | 23875 | 3357 | 8814 | 13607 | 32689 |
| Small grains cut for hay | 8123 | 16291 | 8031 | 19682 | 16154 | 35973 |
| Timothy | 681 | 1408 | 49 | 30 | 730 | 1438 |
| Other tame or cultivated grasses | 10779 | 21034 | 5188 | 11998 | 15967 | 33032 |
| Wild salt or prairie grass | 4031 | 5893 | 218 | 394 | 4249 | 6287 |
| Total grass | 23614 | 44626 | 13486 | 32104 | 37100 | 76730 |
| Corn cut for forage | 214 | 1003 | 626 | 3570 | 840 | 4573 |
| Sorghum kafir for forage | 48 | 374 | 9 | 27 | 57 | 401 |
| Silage crops | 993 | 7176 | 2685 | 23435 | 3678 | 30611 |
| Root crops | 842 | 13619 | 621 | 15717 | 1463 | 29336 |
| Total succulents | 2097 | 22172 | 3941 | 42749 | 6038 | 64921 |
| Small grains including corn for grain | 6059* | 224220* | 1817 | 77692 | 7876* | 301912* |

*Probably 2,600 acres and 100,000 bushels too high on account of non-coast part of Columbia county.

## TOO LITTLE LEGUME HAY

The north Coast district grows more legume hay than the south Coast although the acreage of legume hay in both sections is far too small.

**Grass hay predominates.** As contrasted with the total of 13,607 acres of legumes including 9,031 acres of timothy and clover mixed, there are 37,100 acres, or nearly three times as much, grass hay. Much of this should be replaced by legumes.

**Legumes best yielders.** The figures show an average yield of 800 pounds an acre more hay from legumes and mixed legumes and grass, than from the grass and grain hay. Table VI shows the average yield per acre by crops.

TABLE VI. AVERAGE YIELD PER ACRE OF COAST LEGUMES AND GRASS AND GRAIN HAY 1919

| Crop | Acre yield |
|---|---|
| | *tons* |
| Annual legumes (vetch, peas, with or without oats) | 2.41 |
| Timothy and clover | 2.39 |
| Clover | 2.40 |
| Alfalfa | 2.76 |
| Legume—Average total acres and tonnage | 2.40 |
| Small grain (mostly oats) | 2.23 |
| Timothy | 1.97 |
| Other tame or cultivated grass | 2.07 |
| Wild grass (mostly swamp hay) | 1.48 |
| Grass and grain—Average total acres and tonnage | 2.00 |

**More green feeds and root crops advisable.** An outstanding advantage of Coast land agriculture is its succulent pasture which can be liberally supplemented with green feeds, root crops, and silage. A study of Table V shows that the north Coast section grows relatively little silage. The south Coast grows three times as much. The north Coast grows more acres of roots, but the south Coast harvests a larger total tonnage from fewer acres.

**Economical forage the Coast problem.** Efficient economical forage production is the Coast cropping problem. The survey in Table V shows the need for more legumes in the cropping system. The dairy industry would profit by more green feed, silage, and root crops to supplement pasture and maintain high production.

Results at the Astoria Station show a number of successful legume crops well suited to Coast cropping systems.

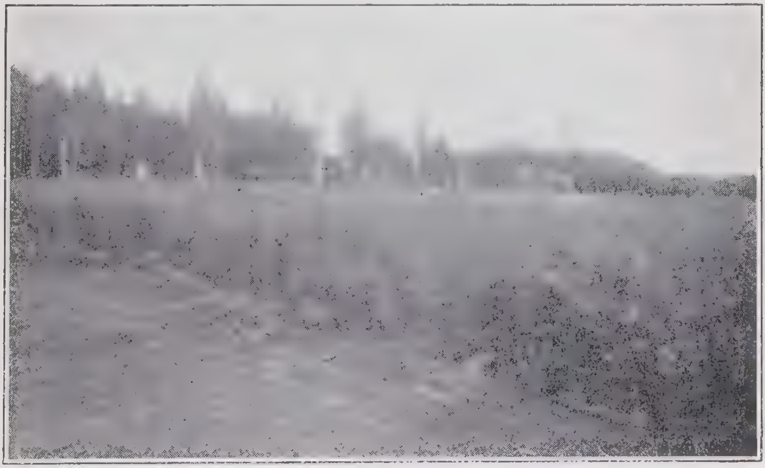

Fig. 1. Clatsop county's first successful field of vetch on upland. Astoria Station July, 1916.

## LEGUMES MUST BE INOCULATED

The Coast counties must grow more legume forage. Figure 1 shows the first successful stand of vetch on the upland in Clatsop county. Success with legumes hinges largely on successful inoculation. Successfully inoculated fields grow legume plants with many small enlargements, or knots, called tubercles or nodules, on the roots. Legume plants having these nodules on the roots are able to secure a considerable part of the plant food, nitrogen, from the air. Plants that are not inoculated do not have these nodules, and they usually die early and do not make a successful crop. The nodule growth on the roots is caused by special kinds of bacteria often called legume bacteria, and a field or a lot of seed is said to be inoculated when these bacteria are present naturally or have been introduced. The process of putting these bacteria on the seed or into the soil of a field is called inoculation.

### Methods of Inoculation

**Inoculated soil.** Two general methods are used. Probably the surest method is to take surface soil from an inoculated field and scatter it thoroughly over the new field to be inoculated and harrow it in. It is best to use moist soil from the surface foot at 400 or more pounds an acre and to distribute it on a cloudy day or toward evening and get it harrowed in so the sunlight will not destroy the bacteria.

**Pure culture.** Another good method is to secure pure culture from the Bacteriology department of the Experiment Station at Corvallis, Oregon, and apply it to the seed. The bacteria are grown in the laboratory and are sent out in small bottles, each of which contains enough to inoculate the seed for two acres. This material costs fifty cents a bottle or at the rate of twenty-five cents per acre. It should be put on the seed just previous to planting as excessive drying seems to kill many of the bacteria.

**Secure right bacteria for each legume.** Since different bacteria inoculate different legume crops it is necessary to get the right kind for each crop, as successful inoculation for clover will not work on vetch or vice versa. Different bacteria are needed for the different crops, and some seem to thrive under more sour soil conditions than others. It has been found that with clover and vetch particularly, better inoculation and better production are secured if lime and manure are used on the field to be inoculated. This usually results in a good crop of vetch or clover with the first sowing.

## PEAS, VETCHES, AND CLOVERS

Field peas, common, purple, and woolly podded vetch planted with oats have given very good results and are probably the best annual legumes for all-round feeding purposes. Peas and purple vetch are probably best for spring sowing and the common and woolly podded vetch for fall sowing.

### Peas

**Peas almost sure crop.** Peas spring planted, while often at a little greater seed expense, are probably the easiest to grow and are surer of a large yield than any of the other legumes, whether fall or spring planted.

Peas have been the most certain of the spring-planted annual legumes, and are suited to most types of tillable lands of the Coast section.

**Manure pays on peas.** Data on soil treatment for peas is limited. Superintendent H. R. Taylor in his report for 1918 said with reference to fertilizers and manure on peas on hill land: "The application of manure proved to be of greater benefit than any of the commercial fertilizers." On old land the use of barnyard manure assures a much larger tonnage of peas. In a single-year trial in 1918 no gain was secured through the use of lime and but little was secured through superphosphate applications.

**Blue Prussian good variety.** Observations on growth and suitability indicate that of the varieties readily available and that have been grown on the station, Blue Prussian is best. The White Canadian is also a good variety though somewhat earlier and shorter. Usually peas are planted with oats as a supporting crop.

**Early sowing necessary.** Peas to be successful must be sowed early. Table VII shows a loss of about a ton an acre a month with delayed sowing.

TABLE VII. TIME OF PLANTING PEAS AND OATS AT ASTORIA STATION IN 1919

| Date of planting | Yields in tons an acre |
|---|---|
| March 14 | 10.45 |
| April 15 | 9.60 |
| May 10 | 8.65 |

Data at other experiment stations and field observations show that one of the most important factors in success with field peas is *early planting.*

**Use plenty of seed.** Ninety to 120 pounds of peas with about 50 pounds of oats is the usual sowing for one acre. When drilled with a grain drill 90 pounds of peas are enough. When broadcasted and disked in, 120 pounds should be used.

Early-planted peas and oats are ready to cut for green feed in mid July. Peas and oats are ready for hay when the pods are about half formed or when the oats are in a soft dough stage. Well cured pea and oat hay is very palatable and readily yields 3½ to 4 tons an acre under good conditions.

**Pea silage good.** Pea-and-oats silage is one of the best silage crops for the north Coast district. The average yield at the Astoria Station was 9.53 tons an acre. Both peas-and-oats and peas-and-barley offer great promise in the warmer south Coast sections, especially where corn silage is not successfully grown.

Peas-and-oats is ready for siloing when in a hard dough stage. Cutting fresh, to short lengths, good packing, and just enough water to exclude air, makes a high-class silage. Care must be exercised not to add too much water to silage in the Coast section; for this reason short cutting and thorough packing are important.

## Vetches

**Inoculation important.** Common vetch is grown to some extent in most Coast counties. Success with it has been variable largely because of difficulty in getting the vetch inoculated. The usual farm experience with vetch has been to plant it one year without success, then replant it on the same land the next year with varying degree of inoculation secured, then replant and get a successful crop with good inoculation. Experiment Station work has proved that vetch on manured land is more easily inoculated and makes good yields.

Liming of inoculated land or the use of lime and manure together with inoculated seed gets successful inoculation of the common vetches the first crop.

**Manure and lime help.** Manure alone, lime alone, and especially lime and manure have given increased yields over similar land unlimed. Tables VIII, IX, and X show the benefit of manure, lime, and lime and manure on a series of plots in the fertilizer trial on the hill land.

TABLE VIII. EFFECT OF MANURE ON YIELD OF VETCH FOR HAY IN TONS AN ACRE

Astoria Experiment Station 1922

| Treatment per acre | Hay per acre: No manure | Hay per acre: Manure at 10 tons per acre | Hay per acre: Gain from manure |
|---|---|---|---|
| | *tons* | *tons* | *tons* |
| Check, no treatment | 1.95 | 2.00 | .05 |
| Lime 3 tons | 3.00 | 3.32 | .32 |
| Lime 2 tons, superphosphate 160 lbs. | 2.20 | 2.92 | .72 |
| Lime 2 tons, potassium chloride 160 lbs. | 2.91 | 3.41 | .50 |
| Superphosphate 160 lbs., potassium chloride 160 lbs. | 1.67 | 2.75 | 1.08 |
| Check, no treatment | 1.15 | 1.90 | .75 |
| Sodium nitrate 160 lbs. | 2.62 | 2.93 | .31 |
| Superphosphate 300 lbs. | 1.17 | 2.20 | 1.03 |
| Potassium chloride 160 lbs. | 1.80 | 2.52 | .72 |
| Sulfur 200 lbs. | 1.80 | 2.70 | .90 |
| Check, no treatment | 1.55 | 2.27 | .72 |
| Average gain | 1.98 | 2.63 | .65 |

TABLE IX. EFFECT OF LIME ON YIELD OF VETCH FOR HAY

Astoria 1922

| | Hay per acre |
|---|---|
| | *tons* |
| Average 3 limed plots | 2.70 |
| Average 3 unlimed plots | 1.55 |
| Gain for lime | 1.15 |

TABLE X. EFFECT OF LIME AND MANURE ON YIELDS OF VETCH FOR HAY

Astoria Station 1922

| | Hay per acre |
|---|---|
| | *tons* |
| Average 3 plots limed and manured | 3.23 |
| Average 3 plots no lime or manure | 1.55 |
| Gain for lime and manure | 1.68 |

**Purple vetch promising.** In the north Coast section common vetch is the most generally grown. In the south Coast, purple vetch spring planted is very successful. Experience on the Astoria Station and in the south Coast and north Coast sections on farms indicates that purple vetch is more easily inoculated than the common vetch. Farm reports indicate that it is highly prized for spring sowing for hay in Coos county. Fig. 2 shows excellent growth of Purple vetch with oats on the station.

Woolly podded vetch, hairy vetch, and Hungarian vetch, and certain mixtures have done well in some trials.

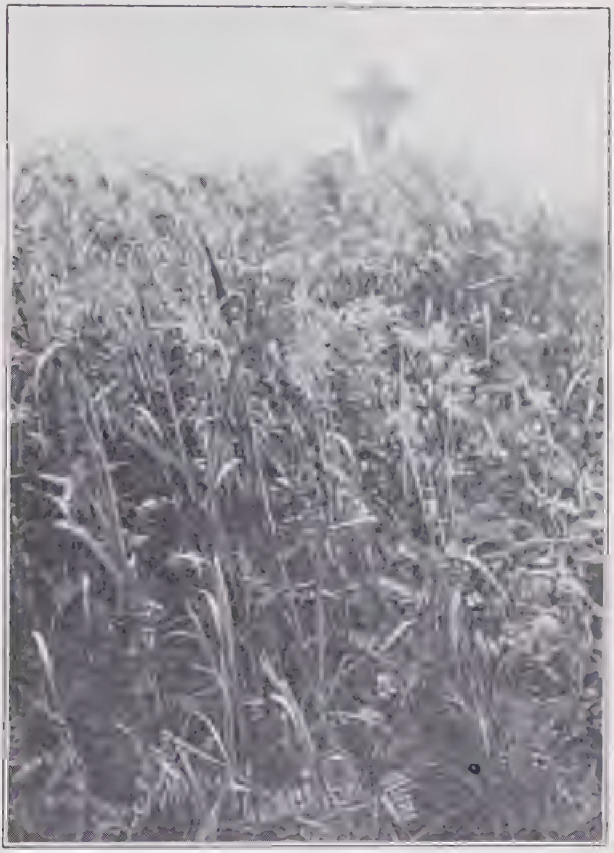

Fig. 2. Purple vetch and oats spring planted for green feed on hay.

TABLE XI. RESULTS OF VARIETY TRIALS OF VETCHES AND OATS SPRING PLANTED ON MANURED, OLD LAND

Astoria, 1923

| | Silage, yield an acre |
|---|---|
| | *tons* |
| Tangier peas and Shadeland Climax oats | 11.97 |
| Common vetch 18805 and Shadeland Climax oats | 10.20 |
| Hairy vetch and Shadeland Climax oats | 9.85 |
| Common vetch and Shadeland Climax oats | 9.21 |
| Common vetch and Gray Winter oats | 8.82 |
| Purple vetch and Gray Winter oats | 6.42 |

TABLE XII. RESULTS OF VARIETY TRIAL OF VETCH AND GRAY WINTER OATS, FALL SOWN

Astoria 1923

| | Silage, yield an acre |
|---|---|
| | *tons* |
| Common vetch and Gray Winter oats | 7.55 |
| Woolly podded vetch and Gray Winter oats | 7.43 |
| Common vetch 13430 and Gray Winter oats | 6.90 |
| Hungarian vetch and Gray Winter oats | 6.89 |
| Pearl vetch and Gray Winter oats | 6.26 |

**Fall or spring sowing?** Vetches are either fall or spring planted. Where serious freezing and thawing does not take place fall sowing is probably best. At Astoria only the hardiest varieties survive some of the winters. Table XIII gives available data on fall and spring sowing of Common vetch and oats. The table shows the superiority of planting spring oats rather than winter oats with vetch in the spring.

TABLE XIII. RESULTS OF SOWING COMMON VETCH WITH OATS IN FALL AND IN SPRING AT ASTORIA

| | Yield an acre | | | | |
|---|---|---|---|---|---|
| | 1918<br>Hay | 1919 | 1921 | 1922 | 1923 |
| | | Silage | | | |
| | *tons* | *tons* | *tons* | *tons* | *tons* |
| Fall sown Common vetch with Gray Winter oats | ........ | 14.10 | Failed | 6.08 | 7.55 |
| Spring sown Common vetch with Gray Winter oats | 2.28 | ........ | ........ | ...... | 8.82 |
| Spring sown Common vetch with spring oats | 3.00 | 9.25 | ........ | ...... | 9.21 |

**Hardy vetches.** The following vetches are listed in the order of their hardiness as determined by a two-year trial at Astoria. Hairy, woolly podded, Hungarian, and common vetch are safe for fall planting, Purple vetch, Tangier peas, and Pearl vetch are too tender for fall sowing.

Vetch is a good spring-planted forage, but it is probable that peas give a better yield and are more easily grown on many unlimed lands. Peas are safely planted later than vetch. Table XIV compares spring-planted peas and common vetch.

TABLE XIV. RESULTS FROM PLANTING PEAS AND OATS AND COMMON VETCH AND OATS IN THE SPRING

Astoria

| | Yield an acre | | |
|---|---|---|---|
| | 1918<br>Hay | 1919<br>Silage | 1923<br>Silage |
| | *tons* | *tons* | *tons* |
| Peas-and-oats | 3.15 | 9.6 | 10.10 |
| Vetch-and-oats | 3.00 | 9.25 | 9.21 |

**Vetch culture.** Vetch and oats when fall planted are usually drilled in at about 60 to 80 pounds an acre with from 40 to 50 pounds of gray winter oats. In the south Coast section red rust-proof oats are often preferred to the gray winter. Fall sowing should take place in late September or early October.

Similar rates of sowing are used in the spring. Early sowing, in late February or early to mid March, is preferred. Spring oats, such as Shadeland Climax or Victory, are very good oats for spring sowing with the vetch. It is probable that in the warmer south Coast section the early spring sowing is of still greater importance.

Where drilling and early planting is practiced smaller rates of sowing may be used. Late sowing requires more seed per acre. The same is true of broadcasting. It is thought that there is less winter killing with drilled than broadcasted seed.

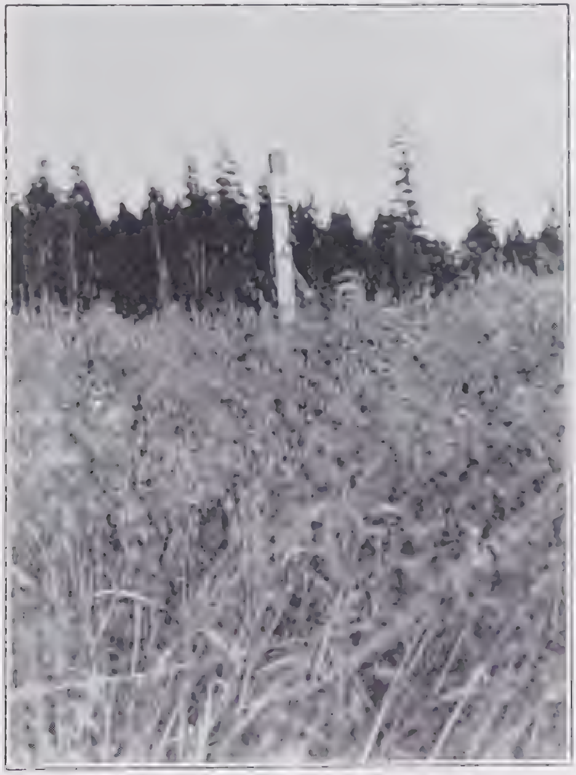

Fig. 3. Oats is the best grain to support the heavy growth of vetch.

**Oats best supporting crop.** In the Coast sections where vetch makes such a rank growth as shown in Fig. 3, it is necessary to plant some supporting crop—usually a cereal. Probably the best all-round crop considering yield, hay value, and supporting power is oats. Wheat is sometimes used but is not so generally satisfactory. Horse beans offer some promise as a supporting crop for spring-planted mixtures for silage, but there is not enough experience with them at the Astoria Station to recommend them for hay or green feed mixtures.

**Time of harvesting.** Vetches are ready for hay when the lower pods are about half filled or when the supporting crop is in the late milk stage. For silage the crop may be put in when the lower pods are well filled, but the seeds still in the soft dough. The quality of vetch hay and silage is not so good when there is ripe seed present. The seed is especially objectionable in the hay.

Well-cured vetch is a high-class dairy hay. It makes excellent green feed and silage and in sections where winter killing does not take place is probably the best annual legume forage.

## Clovers

**Life of clover.** Red and alsike clovers are the most important of the moderately long-lived hay legumes of the Coast. The crop is usually easy to start on new land after it has been burned over. Many sections have difficulty reestablishing a stand afterward, probably because of insufficient lime in the soil for proper maintenance of inoculation. Stands of clover deteriorate rather rapidly without lime or manure, or lime and manure.

Weeds and grasses take the place of the clover.

Table XV shows clover survival on the fertilizer trial.

TABLE XV. EFFECT OF FERTILIZERS ON THE SURVIVAL OF CLOVER AT ASTORIA

| Fertilizer treatment | Percent of clover stand remaining | | | | | |
|---|---|---|---|---|---|---|
| | Without manure | | | With 10 tons manure | | |
| | 1 year after sowing | | 2 years after sowing | 1 year after sowing | | 2 years after sowing |
| | 1920 | 1923 | 1921 | 1920 | 1923 | 1921 |
| Check, no treatment | 25 | 60 | 17 | 50 | 50. | 25 |
| Lime 3 tons per acre | 65 | 60 | 33 | 65 | 50 | 23 |
| Lime 2 tons, superphosphate 160 lbs. | 40 | 50 | 33 | 60 | 60 | 33 |
| Lime 2 tons, potassium chloride 160 lbs. | 35 | 60 | 30 | 65 | 50 | 40 |
| Superphosphate 160 lbs., potassium chloride 160 lbs. | 45 | 55 | 30 | 70 | 55 | 40 |
| Check, no treatment | 45 | 50 | 12 | 65 | 60 | 30 |
| Sodium nitrate 160 lbs. | 40 | 40 | 20 | 60 | 45 | 27 |
| Superphosphate 300 lbs. | 40 | 40 | 10 | 60 | 45 | 20 |
| Potassium chloride 160 lbs. | 25 | 45 | .... | 55 | 45 | 10 |
| Sulfur 200 lbs. | 35 | 40 | 10 | 60 | 50 | 25 |
| Check, no treatment | 40 | 45 | 15 | 60 | 45 | 25 |
| Average | 40 | 49.5 | 19 | 61 | 50.5 | 27 |
| Average 1 year from sowing | 44.8 | | | 55.8 | | |

The survival on manured plots is greater for both the first and second years after sowing.

**Manure and lime help.** There is less difference between manure and no manure in the stand where lime is used. The clover stand the second year from sowing is also much better where lime is used. Especially where manure is used there is less difference between limed and unlimed plots. Both lime and manure are helpful in securing and maintaining a stand of clover. No other fertilizers tried seem to be worth while in maintaining clover stands at Astoria. Table XVI shows this clearly.

TABLE XVI. EFFECT OF LIME ON SURVIVAL OF CLOVER AT ASTORIA

| | Percent of clover remaining on land | | | | | |
|---|---|---|---|---|---|---|
| | Without manure | | | With manure | | |
| | 1 year after sowing | | 2 years after sowing | 1 year after sowing | | 2 years after sowing |
| | 1920 | 1923 | 1921 | 1920 | 1923 | 1921 |
| Average 3 limed plots | 47 | 56.6 | 32 | 63 | 53.3 | 32 |
| Average 8 unlimed plots | 37 | 47 | 14 | 60 | 49.4 | 25 |
| Difference in favor of lime | 10 | 9.6 | 8 | 3 | 3.9 | 7 |

**Sowing clover.** Clover is usually planted in the Coast districts either alone or with a grain or hay crop in the spring. Fall-planted clover is often heaved out and killed by alternate freezing and thawing. Unless the rooting system is well established the crop is likely to be killed. After the first sowing, lime or manure, or lime and manure, is often necessary before the stand can be renewed.

Twelve pounds of red clover or eight pounds of alsike per acre is the usual rate of sowing.

The red clover is best suited to the well-drained bottom-lands and other of the soils not too sour. Alsike is best for the sour hill and tideland soils. A mixture of about nine pounds of red clover with three pounds of alsike is good for mixed land.

**Tested seed best.** Seed of the clover should be tested for purity and germination before purchase and sowing. Two-ounce samples carefully taken to represent the lot may be sent to the Seed Laboratory at the Oregon Agricultural College, Corvallis, Oregon, where the tests are made free of charge. Inoculation of clover in the Coast section is usually unnecessary since Coast soils are often inoculated naturally. This is probably due to the native clover growth in many sections. Where the native clover does not grow, the seed of the first sowing of clover should be inoculated. Culture for this purpose may be had at low cost from the Experiment Station at Corvallis.

**Clover-timothy mixture good.** Clover is sometimes sowed with timothy, especially in the north Coast section. This sowing is usually made in the spring with a nurse crop, using eight pounds of timothy with three pounds of alsike or eight pounds of red clover. For temporary sowing English rye-grass at 15 pounds is very good. The mixture of grass with the clover, especially on limed and manured land, maintains the productiveness through a longer period and helps prevent such serious falling or lodging of the clover. A high percentage of legume in the mixture is desirable. Fig. 4 shows an excellent hay crop of alsike clover and timothy on the Astoria station.

Clover is one of the cheapest and best of the hay crops to produce. It is ready for hay when just past full bloom and reaches this stage at a fairly dry time in the Coast sections.

**Better yields from manure and lime.** Extensive trials have been made showing the effect of fertilizers on yields of clover hay. Lime and manure not only bring about a higher percentage of clover in the stand but also result in better yields of better hay. Table XVII shows effects of lime and manure on hay yield.

TABLE XVII. EFFECT OF LIME ON YIELD OF CLOVER HAY IN TONS AN ACRE

Astoria, 1920, 1921, and 1923

| | |
|---|---|
| | *tons* |
| Average 6 plots 3 years limed | 3.25 |
| Average 16 plots 3 years unlimed | 2.79 |
| Gains from liming | .46 |

Fig. 4. Timothy and plenty of alsike clover make a good hay mixture.

TABLE XVIII. EFFECT OF FERTILIZERS AND MANURE ON YIELD, IN TONS AN ACRE OF CLOVER HAY

Astoria 1920, 1921, and 1923

| Treatment per acre | 3-year average No manure | 3-year average Manure at 10 tons an acre | Gain from manure |
|---|---|---|---|
| | *tons* | *tons* | *tons* |
| Check, no treatment | 2.44 | 2.39 | — .05 |
| Lime 3 tons | 2.85 | 3.85 | 1.00 |
| Lime 2 tons, superphosphate 160 lbs. | 2.65 | 3.58 | .83 |
| Lime 2 tons, potassium chloride 160 lbs. | 2.88 | 3.35 | .47 |
| Superphosphate 160 lbs., potassium chloride 160 lbs. | 2.73 | 3.58 | .85 |
| Check, no treatment | 2.17 | 3.58 | 1.41 |
| Sodium nitrate 160 lbs. | 2.39 | 3.49 | 1.10 |
| Superphosphate 300 lbs. | 1.87 | 3.61 | 1.74 |
| Potassium chloride 160 lbs. | 2.08 | 3.33 | 1.25 |
| Sulfur 200 lbs. | 2.46 | 3.54 | 1.08 |
| Check, no treatment | 2.28 | 2.99 | .71 |
| Average | 2.44 | 3.39 | .95 |

TABLE XIX. EFFECT OF SUPERPHOSPHATE ON YIELD IN TONS AN ACRE OF CLOVER HAY AT ASTORIA

| | |
|---|---|
| | *tons* |
| Average 6 plots 3 years with superphosphate | 3.00 |
| Average 16 plots 3 years without superphosphate | 2.88 |
| Gain | 0.12 |

**Superphosphate appears of little value for clover.** The gain from superphosphate was negligible as is shown by Table XIX. Clover is also a valuable green feed crop and in some sections when mixed with grass is used for silage. Generally it is preferred for hay or green feed and vetch or peas-and-grain is used for silage purposes. Table III shows clover to be the highest yielding of the common hay plants of the Coast region. More should be grown.

**Alfalfa acreage limited.** Alfalfa is at present of small importance in Coast agriculture. Little experimental work has been done with it. It is probable that it is not so well suited to general Coast conditions as peas, vetch, and clover. Present indications are that its culture is not practicable except on deep, well-drained, mellow, warm bottom soils.

Sweet clover seems to offer less promise than alfalfa since its life is so short and it is only suited to conditions similar to those required for alfalfa.

## GRAINS AND GRASSES FOR HAY

Experiments were begun on the tide-land to determine the best grasses for hay. Present results indicate timothy and meadow-foxtail to be the best grasses for the tide-land.

**Oats best forage cereal.** A trial of grains was made for hay in the spring of 1923. General practice of the Coast section is confirmed by results shown in Table XX that oats is the best grain for general Coast use for green feed or hay.

TABLE XX. COMPARISON OF SPRING-SOWN WHEAT AND OATS FOR HAY AT ASTORIA, 1923

| | Hay an acre |
|---|---|
| | *tons* |
| Jenkin Club wheat | 2.73 |
| Shadeland Climax oats | 3.99 |
| Gray Winter oats | 4.15 |

## GRASS FOR GREEN FEED

Japanese barnyard millet is an excellent late summer green feed for the Coast districts. Depending on time of sowing, it is ready for feed from July to October. It is usually planted at 25 to 30 pounds an acre on well-manured land from the middle of April to late June. It sometimes yields as much as eight tons an acre of green feed at a cutting, and on rich bottom-land there may be as many as three cuttings a year from a single sowing. It is broadcasted and harrowed in or is sowed with a drill. While the green feed quality is good, Japanese barnyard millet is not so highly prized for hay.

## ROOTS

Root crop production is a distinctive feature of Coast land agriculture. Like intensive farming conditions of northwest Europe, the Coast region, of small cereal acreage, grows enormous quantities of roots. The principal roots grown are rutabagas, mangels, and turnips, though some carrots are grown in the south Coast section.

**What kind of roots?** There is a preference in the north Coast for rutabagas, probably because of general success in production and because they keep well in the row during the winter. In the south Coast section mangels offer more promise. Turnips are more generally used for summer and early fall feeding, while rutabagas and mangels are fed during winter and early spring. Both leaves and roots are fed to stock when fed directly from the field.

For rather dry sections requiring early planting or where the root maggot is serious on rutabagas, mangels are recommended as the main root crop.

TABLE XXI. COMPARISON OF ROOT TYPES ON UPLAND. ASTORIA, 1923

| | Yields an acre<br>Average of all varieties of each root grown.<br>Turnips 5 plots | <br><br>Rutabagas 8 plots | <br><br>Mangels 9 plots |
|---|---|---|---|
| | *tons* | *tons* | *tons* |
| Roots | 20.66 | 20.26 | 17.83 |
| Leaves | 8.41 | 5.03 | 6.90 |
| Total | 29.07 | 25.29 | 24.73 |
| Roots only of the highest yielding variety | 23.25 | 21.95 | 26.00 |

**Standard root varieties.** Good varieties of roots for the north Coast district are Pomeranian White Globe turnip, Improved American Purple Top and Skirvings Improved rutabagas, and Prizewinner, Mammoth Long Red, and Giant Intermediate mangels. The Pomeranian White Globe turnip is especially prized because of yield and long feeding period without becoming pithy.

Tables XXII, XXIII, and XXVII give the results of root varietal trials of 1923. Owing to inability to secure good seed, the Pomeranian White Globe turnips were not included in the 1923 trial.

### Turnips

TABLE XXII. RESULTS OF TURNIP VARIETY TRIAL IN TONS AN ACRE
Astoria, 1923

| Variety | No. of plots | Roots | Tops | Total |
|---|---|---|---|---|
| | | *tons* | *tons* | *tons* |
| Imperial Green Globe | 2 | 21.65 | 9.72 | 31.37 |
| Green Top Aberdeen | 1 | 20.60 | 6.90 | 25.50 |
| Hardy Round Green | 1 | 19.74 | 8.46 | 28.20 |
| Cow Horn | 1 | 19.67 | 7.27 | 26.94 |

**Turnip culture.** Turnips should be planted about June 20 in rows 30 inches apart and using 2 to 3 pounds of seed an acre. In about a month they are thinned to single plants about 12 inches apart in the row. Late planting avoids much injury from root maggots. It also helps in the eradication of spurry and other weeds. Clean culture should be given. Turnips should be fed in the fall and early winter before they become pithy.

TABLE XXIII. RESULTS OF RUTABAGA VARIETY TRIAL IN TONS AN ACRE

Astoria, 1923

| Variety | No. of plots | Roots | Tops | Total |
|---|---|---|---|---|
| | | *tons* | *tons* | *tons* |
| American Purple Top | 1 | 21.92 | 4.58 | 26.50 |
| Bangholm Grant | 1 | 21.55 | 6.65 | 28.20 |
| Improved American Purple Top | 2 | 21.15 | 3.50 | 24.65 |
| Skirvings Improved | 2 | 19.57 | 6.47 | 26.04 |
| Magnum Bonum | 2 | 18.10 | 4.55 | 22.65 |

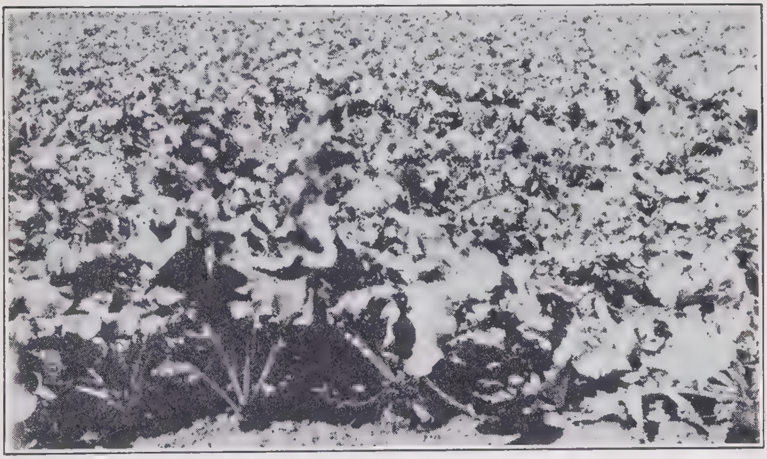

Fig. 5. Improved American Purple top rutabagas fertilized with manure and superphosphate.

## Rutabagas

**Improved seed needed.** There is no constant difference between American and Improved American Purple Top rutabagas. Both of these and Skirvings Improved have done well through many years at Astoria. Fig. 5 shows a heavy crop of rutabagas.

Good seed of rutabagas is important and much good might be accomplished by local seed production from good roots.

Table XXIV shows results of a trial comparing station-grown seed from selected roots with the common commercial stock.

TABLE XXIV. COMPARISON OF YIELD IN TONS AN ACRE FROM SEED OF SELECT ROOTS AND COMMON COMMERCIAL SEED

Astoria, 1919

| | |
|---|---|
| | *tons* |
| Station-selected seed | 30.25 |
| Common seed | 26.45 |
| Gain | 3.80 |

**Manure and superphosphate increase root yields.** Rutabagas and turnip yields are economically increased by liberal use of barnyard manure and superphosphate. Heavy applications, usually at least 20 tons of manure and 400 or more pounds of superphosphate an acre, are necessary. Tables XXV and XXVI show the effect of fertilization on root yields.

TABLE XXV. EFFECT OF FERTILIZER AND MANURE ON YIELDS OF RUTABAGAS GROWN ON DIFFERENT LAND EACH YEAR

Astoria, 1918 and 1919

| Treatment per acre | Yield an acre 1918 | 1919 |
|---|---|---|
| | *tons* | *tons* |
| No manure | 5.57 | ------- |
| Manure 20 tons | 16.36 | 29.25 |
| Manure 20 tons, superphosphate 400 lbs. | 24.98 | 30.25 |
| Manure 20 tons, superphosphate 800 lbs. (1918), 500 lbs. (1919) | 25.75 | 31.52 |
| Manure 20 tons, superphosphate 400 lbs., sulfate of potash 200 lbs. | ------- | 37.27 |

TABLE XXVI. EFFECT OF FERTILIZER ON TURNIPS AND RUTABAGAS GROWN ON MANURED UPLAND

Astoria, 1921

| Treatment per acre | Yield an acre Pomeranian White Globe Turnips | Improved American Purple Top rutabagas |
|---|---|---|
| | *tons* | *tons* |
| Check, no treatment | 21.17 | 20.12 |
| Sulfur 200 lbs. | 23.48 | 20.50 |
| Superphosphate 500 lbs. | 25.93 | 21.96 |
| Superphosphate 1000 lbs. | 27.40 | 33.95 |
| Check, no treatment | 18.25 | 19.83 |
| Superphosphate 500 lbs., potassium chloride 200 lbs. | 25.74 | 16.22 |
| Check, no treatment | 21.82 | 14.03 |

**Cultural directions.** Rutabagas should be planted late enough to avoid root maggot injury. Two to three pounds of seed an acre is sowed in 30- to 36-inch rows June 5 to 20. About a month after planting the rutabagas are thinned to single plants about 12 to 14 inches apart in the row. Delay makes thinning more difficult and reduces the yield. It is best to get the thinning done before time to make hay. Culture is similar to that of turnips.

**Mangels or cow beets.** Mangels are the most promising of the root crops for sections where the season is rather too dry for the late-planted rutabaga crop and where the root maggot causes serious loss. In the lower-rainfall sections mangels are usually best. They are high-grade feed for all classes of stock except breeding rams. Varietal results at Astoria are shown in Table XXVII.

TABLE XXVII. RESULTS OF MANGEL VARIETY TRIAL IN TONS AN ACRE ON MANURED UPLAND

Astoria, 1923

| Variety | Number plots averaged | Roots | Tops | Total |
|---|---|---|---|---|
| | | *tons* | *tons* | *tons* |
| Prize Winner | 2 | 23.40 | 6.00 | 29.40 |
| Mammoth Long Red | 1 | 18.85 | 8.70 | 27.55 |
| Giant Intermediate | 2 | 17.01 | 6.88 | 23.89 |
| Golden Tankard | 2 | 15.54 | 7.74 | 23.28 |
| Half Sugar | 2 | 14.87 | 6.07 | 20.94 |

**Mangel culture.** Mangels should be planted in rows about 30 to 36 inches apart from mid April to the latter part of May. In the south Coast sections the earlier planting may be practiced. About eight pounds an acre of seed is used. The seed should be planted about one to two inches deep. Thinning to about 12 to 14 inches apart in the row should be done when the fourth leaf appears. Culture of mangels is similar to other roots. Mangels are more susceptible to freezing injury than rutabagas. They must be dug and stored for feeding purposes. Cool, dark, dry, well-ventilated storage, conveniently arranged to avoid excessive handling and lifting is desirable. Care should be taken to avoid unnecessary bruising of the roots in handling.

## KALE

Kale is used in some sections of the Coast for cow feeding purposes, but root crops are generally considered more important.

## SOILING CROPS

Any crop that is harvested and fed green is a soiling crop. The most common in the Coast sections are grasses and clovers, Japanese barnyard millet, small grains alone, corn, roots, or combinations of peas and oats, or vetch and oats. Summer soiling crops are most needed in July and August to supplement pasture.

**Green feed keeps up production.** Daily milk-production records for the Astoria Experiment Station herd over a period of three years show an average decrease in production of 25.8 percent for the last of August compared with the last of June. This decrease was also evident in butter-fat deliveries to the Lower Columbia Cooperative Dairy Association in 1923. The June deliveries were 104,869 pounds butter-fat; the

July, 98,810 pounds; the August, 84,892; and the September 72,418 pounds. Compared with June this represents a drop of 5.8 percent for July, 19.1 percent for August, and 31.0 percent for September.

The average of two years' production of the Astoria Station herd when the cows were fed soiling crops to supplement pasture shows a decrease of 16.2 percent for September 1 compared with July 1. These cows were on new pasture that contained abundance of clover.

**Summer pasture needs supplemental feed.** Pastures during the warm weather do not appear to be as palatable as in June. At least the cows do not consume enough to maintain maximum production even when pasturage is available. By the use of soiling crops with pasturage a dairyman may expect an increase of about ten percent over pasturage alone.

The aim in growing soiling crops should be to produce the maximum yield of nutritious, palatable feed per acre. Legume crops for green feed are preferable. High yield will prevent coarseness and waste, requires less land for a given number of cows, and requires less labor because of smaller area to cut each day. Large yields and a dense stand can be secured by heavy seeding and a liberal use of manure.

The labor cost of harvesting and feeding soiling crops is high. Low costs should be maintained. The crops may be fed to the individual cows while they are being milked, or hauled to the pasture, letting the cows eat off the rack. The latter does not favor the highest producing cows but it usually is the cheaper practice. Soiling crops should be grown as near as possible to the place of feeding to keep labor costs low.

**Roots fed directly.** Roots for winter feeding are handled directly from the field. Enough is hauled at one time for two or three days during fall and early winter. With the possibility of a cold-weather period, roots for ten days may be kept in the barn. The tops and roots are fed and both are good feed. The roots do not need to be cut for the cows, as they soon learn to eat the whole root. Mangels should be stored before November 15 to prevent a loss from freezing in the field. All roots are approximately of the same feeding value. Turnips and rutabagas must be fed after milking in order to prevent a taste in the milk or cream. Even as small an amount as fifteen pounds of roots will flavor milk if fed before milking. Fifty or more pounds a day will flavor the milk no matter when fed.

As the price of dairy products and the value of land advance and dairying becomes more intensive more soiling crops must be used.

**Cropping system for soiling crop production.** Table XXVIII gives complete information for a cropping system to provide soiling crops. The system given is based upon the results of experiments with many crops. It has been used satisfactorily in providing green feed for the station dairy herd. Table XXVIII is intended to serve as a guide in planting to produce green feed either for the entire year or for any part of the year. The feeding dates are approximate, and the area necessary to produce feed for ten cows is based upon average yields. The table will be of widest use for dairymen who are following an intensive dairying system. For extensive

TABLE XXVIII. CROPPING SYSTEM FOR GREEN FEED PRODUCTION ON HILL LAND

| Crop and variety | Rate of planting | Date of planting | Fertilizer to acre | Feeding date | Acreage required for 10 cows |
|---|---|---|---|---|---|
| | *lbs.* | | | | |
| Common vetch and<br>Gray winter oats | 60<br>50 | Sept. 20 to October 20 | 10 tons manure | June 20-July 20 | ½ acre |
| Common vetch and<br>Gray winter oats | 60<br>50 | Feb. 15 to March 15 | 10 tons manure | July 1-July 25 | ½ acre |
| Field peas and<br>Gray winter oats | 100<br>50 | Feb. 15 to March 15 | 10 tons manure | July 1-July 20 | ⅜ acre |
| Field peas and<br>Shadeland Climax oats | 100<br>60 | March 15 to April 10 | 10 tons manure | July 10-Aug. 1 | ½ acre |
| Japanese barnyard millet | 25-30 | May 1 to June 10 | 15 to 20 tons manure | Aug. 1-Sept. 10 | ¾ acre |
| Turnips<br>Pomeranian White Globe or Imperial Green Globe | 2-3 | June 5 to June 15 | 15 to 20 tons manure, 400 lbs. superphosphate | Sept. 10-Nov. 1 | ½ acre |
| Rutabagas or mangels<br>Improved American Purple Top or<br>Skirvings Improved or Prizewinner Mangels | 2-3<br>8-10 | June 5 to June 20<br>May 15 to June 1 | 20 to 25 tons manure, 500 lbs. superphosphate | Nov. 1-March 20 | 1¼ acres |

dairying part of the information will be of use to provide green feed for times when there is a shortage of pasture or to supplement silage. The whole or parts can be followed profitably by the dairyman of limited capital or the dairyman with a herd too small to warrant construction of a silo.

**Better yields from tide-land and bottom-land.** The table is prepared for hill land. It will apply to tide-land or bottom-land except that a larger yield can be expected and less manure will be required. For tide-land or bottom-land no manure need be used for vetches or peas as these crops will produce an average yield without manure. Under average conditions 3 to 3¼ acres will produce soiling crops for ten cows where they have the use of pasture.

## SILAGE CROPS

Silage is desirable on the dairy farm to furnish a cheap source of succulence for summer or winter feed. It reduces the amount of hay required by about 40 percent. It keeps the cow in better condition than when roots are fed alone. Many crops may be successfully stored in a silo. The better the crop the better the silage. The more food value the crop contains the more the cow will receive when the silage is fed.

**Peas and oats good silage.** Corn is the standard silage crop of the United States. Corn is not grown extensively or successfully in the north Coast region. Unless a yield of ten tons or more per acre can be secured it will be found advantageous to grow other crops. Probably the best Coast silage crop is peas-and-oats.

Oats is the crop used now most extensively for silage purposes. If cut at the proper time it makes a good silage that is relished by the cows. Better and more palatable silage is secured if peas or vetch is grown with the oats. Considering yield and feeding value peas-and-oats and vetch-and-oats are more satisfactory than oats alone.

**Silage making important.** The most important factors in the production of good silage are maturity and packing. The proper maturity has been discussed under the crop. In producing good silage from small grains the finer the silage is cut the better it packs and the less tendency to mold. Two men should be in the silo tramping at all times. It is usually a good practice for the owner to be in the silo himself. Tramping rather than the use of water should be depended upon to remove the air. Water should be added particularly with hollow-stemmed silage or when the forage has dried out and wilted badly. Green or slightly wilted crops usually do not require water. The addition of surplus water results in poor silage. The silo may be topped out or sealed with waste materials, such as ferns, wild grasses, or sedges.

## HAY CROPS

**Legume hay best.** The value of the hay crop depends on three things: the amount of legumes present, the stage of cutting, and the manner of curing. The importance of a large percentage of legumes has been discussed at some length. Too much importance can not be placed on the stage of cutting. Hay that has been allowed to become too ripe is similar to straw as most of the food value has passed into the seed. Fine stemmed, green, leafy hay is best.

**Prompt curing necessary.** Hay should be cured and hauled as soon as possible. Exposure for any length of time to either sun or rain very materially decreases its value. If it is impossible to haul immediately, allow it to cure in the shock. Care should be taken in handling of clover so as to prevent a loss of leaves. Good hay should have a green color and a pleasant odor.

## PASTURE CROPS

**More experiments needed.** Pasture experiments at the Astoria Station have been limited, and the results of these trials together with observations and data secured from the various Coast counties are made the basis for the following discussion and recommendations.

**Pasture important.** The pasture crop of the Coast district is probably its most important forage crop. The large areas of rough land subject to washing, stump land with too great a clearing expense, poorly drained land, and some tide-land having too many buried logs and roots, are adapted, for the present at least, only to pasturing. Many acres of plow land in this Coast district of cool summers and frequent summer rains are now producing profitable pasture crops.

The climate and soil of the Coast district is generally better suited to the moisture-loving and acid-tolerant grasses and legumes. There is a tendency for Coast land pastures without lime or manure to become pretty much occupied by acid-tolerant grasses, as Red Top and Creeping Bent grass.

**Good grasses.** Of the short-lived perennial grasses suited to pasture conditions, English rye-grass, Italian rye-grass, and timothy are productive and commonly used. English rye-grass is normally finer in growth and somewhat longer lived than the Italian rye-grass.

Kentucky blue-grass is not so good for the sour soils but does well on some of the well-drained bottom-lands. On the more sour hill soils and tide-land soils it should usually be replaced to a considerable extent with redtop, or creeping bent grass.

Orchard-grass should be included in all upland mixtures and may usually be advantageously used on both the bottom- and the tide-land types. It is especially good on fern land. Tall oat grass is most likely to be useful in mixtures on the dryer hill soils.

Meadow-foxtail is an early, long-lived, sod-forming perennial especially useful on tide-land or other moist, sour soils. Seed of meadow-foxtail is often of poor quality.

Reed canary-grass is a remarkably productive and valuable perennial grass suited to wet tide-lands and other bottom lands and is commonly grown for hay and pasture in the southwest Coast district. It is said that in old reed canary-grass meadows practically everything but reed canary-grass and creeping bent grass is crowded out.

Of the legumes for Coast land pasture white clover, Ladino white clover, and alsike seem best. Without lime and manure the tendency is for the legumes to be gradually eliminated from the pastures.

**Starting pastures.** Coast pastures are often started by burning over land in the early fall, then sowing the grass seed on the dry ashes as soon as they have cooled. This sowing should take place early, as in August or early September in sections where freezing and thawing is likely to take place. In districts where heaving caused by freezing and thawing is likely to happen, spring sowing is best. The seed bed should be rather fine and firm underneath. Owing to the variable quality of grass seed it is usually best to have the seed tested previous to preparing the mixture. Shallow sowing is necessary because of the small size of grass seed.

**Pasture mixtures.** Recommended pasture mixtures follow.

### Hill Land

| | lbs. |
|---|---|
| English rye-grass | 5 |
| Orchard-grass | 4 |
| Tall oat-grass | 2 |
| Timothy | 3 |
| Kentucky blue-grass | 1 |
| Redtop | 1 |
| Alsike clover | 1 |
| White clover | ½ |
| | 17½ |

Sow at 16 to 25 pounds an acre depending on seed quality.

### Bottom-land

| | |
|---|---|
| English rye-grass | 5 |
| Orchard-grass | 4 |
| Tall oat-grass | 2 |
| Timothy | 3 |
| Kentucky blue-grass | 3 |
| White or Ladino clover | ½ |
| Red clover | 3 |
| | 20½ |

Sow at 16 to 25 pounds an acre depending on quality of seed.

### Well-drained Tide-land

| | |
|---|---|
| English rye-grass | 5 |
| Orchard-grass | 4 |
| Timothy | 3 |
| Meadow-foxtail | 4 |
| Redtop | 2 |
| Alsike clover | 2 |
| White clover | 1 |
| | 21 |

Sow at 18 to 25 pounds an acre.

### Bottom- or Tide-land, Subject to High Water Table and Winter Overflow

| | |
|---|---|
| Reed canary-grass | 3 |
| Creeping bent grass | 2 |
| Meadow-foxtail | 4 |
| Timothy | 5 |
| Alsike | 2 |
| | 16 |

Sow at 16 pounds an acre.

**Pasture management.** The young grass should not be pastured until it is well established and stock should be kept off when the ground is soft. The pasture should be kept eaten off rather closely, but should not be fed off so closely as to expose the grass crowns or too greatly limit the leaf surface. Where the stock cannot keep the pasture eaten down, an occasional mowing is a good thing to keep the grass from becoming too coarse and to keep weeds in check. Pastures should be harrowed to scatter manure. Bare spots should be reseeded and care should be taken to keep out weeds and brush. Applications of barnyard manure from time to time will keep the growth more luxuriant and help to maintain the better grasses and prevent weeds. Applications of lime will help in the development of many of the grasses, and also maintain a better stand of the clovers. Weedy pastures in many cases must be plowed and reseeded. Productive palatable pasture is probably the cheapest forage in the Coast district.

Station Bulletin 204 May, 1924

Oregon Agricultural College

Experiment Station

# Spring Crops for Eastern Oregon

By

David E. Stephens
Robert Withycombe
Obil Shattuck

1885

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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# Spring Crops for Eastern Oregon

By

David E. Stephens

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## INTRODUCTION

In the counties of Oregon east of the Cascade Mountains, the cereals —wheat, barley, oats, rye, and corn—constitute one of the chief sources of farm income. In the Columbia River Basin counties of Sherman, Gilliam, Morrow, and Umatilla the income from cereals exceeds that from all other farm products combined. Their value in 1919 in these four counties exceeded 20½ million dollars or about 80 percent of the value of all crops, including hay and forage, most of which was grain hay. The cereals are also important crops in Wasco, Union, Baker, Wallowa, and Jefferson counties.

In Eastern Oregon, wheat and rye generally are fall sown, the winters being too severe in most of the area for the successful production of winter barley or oats. When wheat is fall sown, it generally is preceded by a season of fallow. The production of wheat after fallow is discussed in Oregon Station Bulletin 190. In the present bulletin, the growing of spring-sown crops only is considered.

## FALL-SOWN CROPS GENERALLY MOST PRODUCTIVE

When not injured by freezing, fall-sown grains usually are more productive than those sown in the spring. In most parts of Eastern Oregon, wheat and rye are the only safe grain crops to sow in the fall. In limited areas, winter barley, too, will survive. Fall-sown oats cannot be grown successfully.

The experience of farmers on the dry lands of Eastern Oregon, and the results obtained on the Branch Experiment Stations, show that wheat, when fall sown, will produce higher acre yields than when spring sown, especially when grown after summer fallow. Winter barley, also, if not injured by cold weather, will usually outyield spring barley. Winter rye at Moro, when grown after fallow, has not proved quite so productive as spring rye, but neither winter rye nor spring rye has produced seed yields as high as winter or spring wheat. At the Burns Station, spring rye has been the most dependable dry-land crop.

In addition to increased yields, the sowing of grain in the fall, whenever possible, more equally distributes farm labor. The spring is a busy time for the Eastern Oregon farmer, and if he has much spring seeding to do, other important work may have to be neglected. To obtain best results, spring grain must be sown as early in the spring as possible.

## NECESSITY OF SOMETIMES SOWING SPRING CROPS

Unfavorable autumn weather, failure to get stands of winter grain, and occasionally the inability to take off in time a growing crop, may make the sowing of spring grain advisable. Spring grain may also sometimes fit better into a crop rotation than winter grain.

In locations so dry that winter wheat will not emerge in the fall, or where late spring or early summer frosts are prevalent, the growing of spring grain may prove more profitable in the long run than growing winter wheat. At Burns, where these conditions exist, Baart, the best yielding spring wheat on dry land, has produced a ten-year average of 6.27 bushels an acre more than Turkey, the best winter variety. When sown after a crop the previous year, or when irrigated, spring grain also may prove more productive than winter grain. Results at Burns show that the best spring varieties, Federation and Dicklow, on irrigated land made a four-year average yield of 64.4 and 61.1 bushels respectively as against similar averages for Turkey and Hybrid No. 128 winter varieties, of 48.7 and 37.8 bushels, or an average difference of 19.5 bushels an acre in favor of spring wheat under irrigation. For most locations in Eastern Oregon, however, the sowing of winter grain, especially winter wheat, is strongly recommended in preference to a spring-sown crop for growing after a season of fallow.

## DISTRIBUTION, YIELD, AND ACRE VALUE OF THE SMALL GRAINS IN OREGON

TABLE I. AVERAGE ACREAGE, PRODUCTION, ACRE YIELD, AND ACRE VALUE OF WINTER WHEAT, SPRING WHEAT, OATS, AND BARLEY IN OREGON BY COUNTIES FOR THE FIVE-YEAR PERIOD, 1919 TO 1923, INCLUSIVE

| | Acreage | Production in bushels | Bushels per acre | Pounds per acre | Value per acre |
|---|---|---|---|---|---|
| *Oregon* | | | | | |
| Winter wheat | 834,406 | 18,948,878 | 22.7 | 1362 | $18.16 |
| Spring wheat | 263,171 | 3,981,559 | 15.2 | 912 | 12.16 |
| Oats | 283,913 | 9,241,081 | 32.4 | 1037 | 14.26 |
| Barley | 74,311 | 2,246,034 | 29.9 | 1435 | 17.34 |
| *Eastern Oregon* | | | | | |
| Winter wheat | 640,384 | 14,507,958 | 22.5 | 1350 | 18.00 |
| Spring wheat | 197,070 | 2,953,788 | 15.2 | 912 | 12.16 |
| Oats | 34,133 | 1,105,382 | 32.1 | 1027 | 14.12 |
| Barley | 58,008 | 1,728,250 | 29.5 | 1416 | 17.11 |
| *Baker* | | | | | |
| Winter wheat | 5,070 | 93,203 | 19.2 | 1152 | 15.36 |
| Spring wheat | 12,847 | 252,046 | 19.8 | 1188 | 15.84 |
| Oats | 5,228 | 197,725 | 38.4 | 1229 | 16.90 |
| Barley | 4,353 | 159,530 | 36.0 | 1728 | 20.88 |
| *Crook* | | | | | |
| Winter wheat | 813 | 13,149 | 16.6 | 996 | 13.28 |
| Spring wheat | 6,212 | 121,470 | 19.2 | 1152 | 15.36 |
| Oats | 1,280 | 49,301 | 35.6 | 1139 | 15.66 |
| Barley | 838 | 27,699 | 29.6 | 1421 | 17.17 |
| *Deschutes* | | | | | |
| Winter wheat | 142 | 2,362 | 16.4 | 984 | 13.12 |
| Spring wheat | 1,188 | 23,429 | 19.4 | 1164 | 15.52 |
| Oats | 1,384 | 41,277 | 28.6 | 915 | 12.58 |
| Barley | 214 | 7,263 | 30.4 | 1459 | 17.63 |

TABLE I *(concluded)*. WINTER AND SPRING GRAINS IN OREGON

| | Acreage | Production in bushels | Bushels per acre | Pounds per acre | Value per acre |
|---|---|---|---|---|---|
| *Gilliam* | | | | | |
| Winter wheat | 80,675 | 1,468,606 | 17.6 | 1056 | $14.08 |
| Spring wheat | 19,826 | 241,338 | 13.0 | 780 | 10.40 |
| Oats | 256 | 3,722 | 14.6 | 467 | 6.42 |
| Barley | 3,984 | 81,963 | 20.0 | 960 | 11.60 |
| *Grant* | | | | | |
| Winter wheat | 652 | 12,350 | 19.0 | 1140 | 15.20 |
| Spring wheat | 1,109 | 18,605 | 16.2 | 972 | 12.96 |
| Oats | 671 | 20,614 | 31.6 | 1011 | 13.90 |
| Barley | 464 | 13,626 | 28.8 | 1382 | 16.70 |
| *Harney* | | | | | |
| Winter wheat | 179 | 2,674 | 12.4 | 744 | 9.92 |
| Spring wheat | 992 | 17,052 | 16.8 | 1008 | 13.44 |
| Oats | 650 | 12,366 | 18.6 | 595 | 8.18 |
| Barley | 1,150 | 29,382 | 24.0 | 1152 | 13.92 |
| *Hood River* | | | | | |
| Winter wheat | 147 | 3,555 | 24.4 | 1464 | 19.52 |
| Spring wheat | 328 | 6,598 | 20.2 | 1212 | 16.16 |
| Oats | 296 | 11,261 | 36.4 | 1164 | 16.01 |
| Barley | 77 | 2,731 | 34.4 | 1651 | 19.95 |
| *Jefferson* | | | | | |
| Winter wheat | 16,128 | 206,630 | 13.2 | 792 | 10.56 |
| Spring wheat | 31,130 | 274,410 | 8.5 | 510 | 6.80 |
| Oats | 738 | 11,390 | 16.0 | 512 | 7.04 |
| Barley | 741 | 14,136 | 19.0 | 912 | 11.02 |
| *Klamath* | | | | | |
| Winter wheat | 1,339 | 20,725 | 15.4 | 924 | 12.32 |
| Spring wheat | 10,223 | 172,051 | 17.0 | 1020 | 13.60 |
| Oats | 3,262 | 108,623 | 33.6 | 1075 | 14.78 |
| Barley | 3,978 | 127,249 | 31.2 | 1498 | 18.09 |
| *Lake* | | | | | |
| Winter wheat | 2,097 | 32,603 | 16.0 | 960 | 12.80 |
| Spring wheat | 10,977 | 223,872 | 19.4 | 1164 | 15.52 |
| Oats | 820 | 30,804 | 35.0 | 1120 | 15.40 |
| Barley | 1,236 | 37,937 | 30.4 | 1459 | 17.63 |
| *Malheur* | | | | | |
| Winter wheat | 783 | 22,277 | 26.8 | 1608 | 21.14 |
| Spring wheat | 4,677 | 121,881 | 25.2 | 1512 | 20.16 |
| Oats | 1,046 | 42,882 | 40.6 | 1299 | 17.86 |
| Barley | 3,224 | 133,961 | 41.2 | 1978 | 23.90 |
| *Morrow* | | | | | |
| Winter wheat | 98,542 | 1,641,560 | 16.2 | 972 | 12.96 |
| Spring wheat | 17,149 | 180,862 | 11.2 | 672 | 8.96 |
| Oats | 235 | 5,192 | 18.2 | 582 | 8.01 |
| Barley | 5,044 | 97,722 | 19.6 | 941 | 11.37 |
| *Sherman* | | | | | |
| Winter wheat | 116,247 | 2,680,475 | 23.2 | 1392 | 18.56 |
| Spring wheat | 9,465 | 142,372 | 15.2 | 912 | 12.16 |
| Oats | 1,192 | 26.070 | 21.6 | 691 | 9.50 |
| Barley | 3,156 | 74,734 | 23.6 | 1133 | 13.69 |
| *Umatilla* | | | | | |
| Winter wheat | 214,067 | 5,855,113 | 27.3 | 1638 | 21.84 |
| Spring wheat | 16,993 | 297,585 | 17.6 | 1056 | 14.08 |
| Oats | 799 | 23.587 | 29.6 | 947 | 13.02 |
| Barley | 14,444 | 449,575 | 31.2 | 1498 | 18.10 |
| *Union* | | | | | |
| Winter wheat | 26,190 | 681,012 | 25.6 | 1536 | 20.48 |
| Spring wheat | 28,025 | 491,818 | 18.4 | 1104 | 14.72 |
| Oats | 9,440 | 306,271 | 32.2 | 1030 | 14.17 |
| Barley | 5,265 | 162,391 | 31.6 | 1517 | 18.33 |
| *Wallowa* | | | | | |
| Winter wheat | 16,844 | 335,310 | 19.6 | 1176 | 15.68 |
| Spring wheat | 18,799 | 266,852 | 14.4 | 864 | 11.52 |
| Oats | 5,258 | 174,257 | 32.6 | 1043 | 14.34 |
| Barley | 5,031 | 169,309 | 33.4 | 1603 | 19.37 |

TABLE I *(continued)*. WINTER AND SPRING GRAINS IN OREGON

| | Acreage | Production in bushels | Bushels per acre | Pounds per acre | Value per acre |
|---|---|---|---|---|---|
| *Wasco* | | | | | |
| Winter wheat | 57,718 | 1,386,086 | 23.8 | 1428 | $19.04 |
| Spring wheat | 6,106 | 90,856 | 14.6 | 876 | 11.68 |
| Oats | 1,183 | 32,852 | 27.4 | 877 | 12.06 |
| Barley | 3,908 | 115,954 | 29.8 | 1430 | 17.28 |
| *Wheeler* | | | | | |
| Winter wheat | 2,752 | 50,270 | 17.6 | 1056 | 14.08 |
| Spring wheat | 1,024 | 10,692 | 10.4 | 624 | 8.32 |
| Oats | 394 | 7,181 | 17.2 | 550 | 7.57 |
| Barley | 905 | 23,097 | 23.6 | 1133 | 13.69 |
| *Western Oregon* | | | | | |
| Winter wheat | 194,022 | 4,440,920 | 22.8 | 1368 | 18.24 |
| Spring wheat | 66,102 | 1,027,771 | 15.4 | 924 | 12.32 |
| Oats | 249,780 | 8,135,699 | 32.4 | 1037 | 14.26 |
| Barley | 16,300 | 517,784 | 31.5 | 1512 | 18.27 |
| *Benton* | | | | | |
| Winter wheat | 10,345 | 212,551 | 20.4 | 1224 | 16.32 |
| Spring wheat | 4,754 | 72,696 | 15.2 | 912 | 12.16 |
| Oats | 13,976 | 376,756 | 27.0 | 864 | 11.88 |
| Barley | 877 | 23,170 | 26.2 | 1258 | 15.20 |
| *Clackamas* | | | | | |
| Winter wheat | 18,887 | 507,147 | 26.8 | 1608 | 21.44 |
| Spring wheat | 3,214 | 64,781 | 20.0 | 1200 | 16.00 |
| Oats | 26,966 | 1,022,098 | 37.8 | 1210 | 16.63 |
| Barley | 692 | 24,821 | 36.0 | 1728 | 20.88 |
| *Clatsop* | | | | | |
| Winter wheat | 52 | 1,598 | 30.2 | 1812 | 24.16 |
| Spring wheat | 25 | 580 | 23.2 | 1392 | 18.56 |
| Oats | 550 | 26,789 | 47.8 | 1530 | 21.03 |
| Barley | 17 | 630 | 35.8 | 1718 | 20.76 |
| *Columbia* | | | | | |
| Winter wheat | 830 | 21,775 | 26.2 | 1572 | 20.96 |
| Spring wheat | 403 | 9,197 | 22.8 | 1368 | 18.24 |
| Oats | 2,461 | 113,538 | 46.2 | 1478 | 20.33 |
| Barley | 215 | 8,939 | 41.0 | 1968 | 23.78 |
| *Coos* | | | | | |
| Winter wheat | 93 | 2,708 | 28.8 | 1728 | 23.04 |
| Spring wheat | 265 | 6,450 | 24.0 | 1440 | 19.20 |
| Oats | 1,374 | 74,378 | 51.2 | 1638 | 22.53 |
| Barley | 931 | 56,252 | 57.2 | 2746 | 33.18 |
| *Curry* | | | | | |
| Winter wheat | 26 | 606 | 23.0 | 1380 | 18.40 |
| Spring wheat | 18 | 348 | 18.6 | 1116 | 14.88 |
| Oats | 93 | 4,199 | 45.4 | 1453 | 19.98 |
| Barley | 51 | 1,985 | 38.4 | 1843 | 22.27 |
| *Douglas* | | | | | |
| Winter wheat | 9,263 | 166,534 | 18.0 | 1080 | 14.40 |
| Spring wheat | 4,039 | 59,385 | 14.6 | 876 | 11.68 |
| Oats | 10,691 | 266,033 | 24.8 | 794 | 10.91 |
| Barley | 1,669 | 40,276 | 24.0 | 1152 | 13.92 |
| *Jackson* | | | | | |
| Winter wheat | 8,170 | 172,925 | 21.2 | 1272 | 16.96 |
| Spring wheat | 1,971 | 32,062 | 16.0 | 960 | 12.80 |
| Oats | 1,037 | 37,341 | 33.8 | 1082 | 14.87 |
| Barley | 2,841 | 94,219 | 32.2 | 1546 | 18.68 |
| *Josephine* | | | | | |
| Winter wheat | 1,535 | 25,886 | 17.0 | 1020 | 13.60 |
| Spring wheat | 589 | 7,852 | 13.2 | 792 | 10.56 |
| Oats | 840 | 26,308 | 30.0 | 960 | 13.20 |
| Barley | 706 | 18,783 | 26.6 | 1277 | 15.43 |
| *Lane* | | | | | |
| Winter wheat | 16,780 | 306,090 | 18.2 | 1092 | 14.56 |
| Spring wheat | 13,184 | 178,879 | 13.4 | 804 | 10.72 |
| Oats | 21,761 | 539,125 | 24.4 | 780 | 10.73 |
| Barley | 1,444 | 38,189 | 26.4 | 1267 | 15.31 |

TABLE I *(continued)*. WINTER AND SPRING GRAINS IN OREGON

| | Acreage | Production in bushels | Bushels per acre | Pounds per acre | Value per acre |
|---|---|---|---|---|---|
| *Lincoln* | | | | | |
| Winter wheat | 304 | 5,640 | 18.9 | 1134 | $15.12 |
| Spring wheat | 80 | 1,222 | 15.4 | 924 | 12.32 |
| Oats | 1,043 | 35,429 | 34.2 | 1094 | 15.04 |
| Barley | 21 | 653 | 29.6 | 1421 | 17.17 |
| *Linn* | | | | | |
| Winter wheat | 24,280 | 486,481 | 19.6 | 1176 | 15.68 |
| Spring wheat | 17,012 | 241,983 | 14.0 | 840 | 11.20 |
| Oats | 47,337 | 1,333,111 | 28.2 | 902 | 12.41 |
| Barley | 2,241 | 64,980 | 29.2 | 1402 | 16.94 |
| *Marion* | | | | | |
| Winter wheat | 32,899 | 786,965 | 23.8 | 1428 | 19.04 |
| Spring wheat | 10,498 | 174,499 | 16.4 | 984 | 13.12 |
| Oats | 42,233 | 1,420,372 | 33.4 | 1069 | 14.70 |
| Barley | 1,606 | 52,358 | 32.8 | 1574 | 19.02 |
| *Multnomah* | | | | | |
| Winter wheat | 1,446 | 39,351 | 26.8 | 1608 | 21.44 |
| Spring wheat | 763 | 17,220 | 22.8 | 1368 | 18.24 |
| Oats | 4,230 | 171,579 | 39.8 | 1274 | 17.51 |
| Barley | 429 | 15,226 | 35.8 | 1718 | 20.76 |
| *Polk* | | | | | |
| Winter wheat | 5,137 | 600,584 | 23.8 | 1428 | 19.04 |
| Spring wheat | 3,696 | 59,704 | 16.4 | 984 | 13.12 |
| Oats | 25,659 | 807,556 | 31.2 | 998 | 13.73 |
| Barley | 1,155 | 32,664 | 28.0 | 1344 | 16.24 |
| *Tillamook* | | | | | |
| Winter wheat | ...... | ...... | ...... | ...... | ...... |
| Spring wheat | ...... | ...... | ...... | ...... | ...... |
| Oats | ...... | ...... | ...... | ...... | ...... |
| Barley | ...... | ...... | ...... | ...... | ...... |
| *Washington* | | | | | |
| Winter wheat | 19,119 | 497,251 | 25.8 | 1548 | 20.64 |
| Spring wheat | 2,711 | 51,170 | 19.4 | 1164 | 15.52 |
| Oats | 24,961 | 1,071,390 | 42.8 | 1369 | 18.83 |
| Barley | 660 | 22,410 | 33.6 | 1613 | 19.48 |
| *Yamhill* | | | | | |
| Winter wheat | 24,855 | 606,827 | 24.3 | 1458 | 19.44 |
| Spring wheat | 2,879 | 49,743 | 17.4 | 1044 | 13.92 |
| Oats | 24,568 | 809,701 | 33.2 | 1062 | 14.61 |
| Barley | 743 | 22,229 | 30.2 | 1450 | 17.52 |

In Table I acreage and production data are given for Oregon, by counties, for winter wheat, spring wheat, oats, and barley. The figures are averages for the five-year period 1919 to 1923, inclusive, taken from reports compiled by F. L. Kent, Agricultural Statistician for Oregon of the United States Department of Agriculture.

Table I also gives the yields of these crops by counties and the value per acre of each crop based on the ten-year average farm price in Oregon from 1905 to 1914, inclusive. The average farm price per bushel for these crops for this period, according to the 1914 Yearbook of the United States Department of Agriculture, was as follows: wheat, 80 cents; barley, 58 cents; and oats, 44 cents per bushel. The price per ton based on these values would be $26.67 for wheat, $24.17 for barley, and $27.50 for oats. The ten-year average farm price per bushel for the years 1913 to 1922, inclusive (Yearbook, 1922) in Oregon was $1.32 for wheat, $0.88 for barley, and $0.59 for oats. Based on these prices, wheat was worth $44.00, barley $36.67, and oats $36.88 per ton.

Based on five-year average yields and ten-year pre-war average prices, the acre value of winter wheat for the state was $18.16; of barley

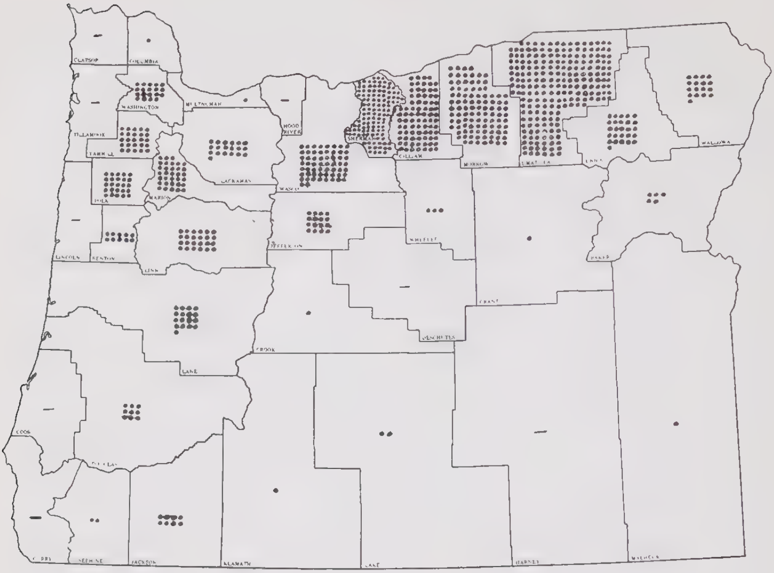

Fig. 1. Winter wheat acreage in Oregon, averages for 1919-1923 inclusive. Each dot represents one thousand acres; each dash represents less than five hundred acres.

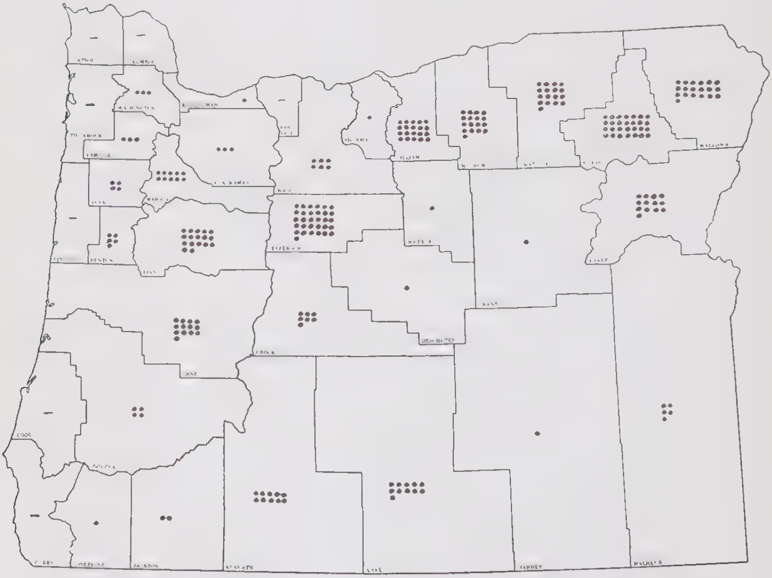

Fig. 2. Spring wheat acreage in Oregon, averages for 1919-1923 inclusive. Each dot represents one thousand acres; each dash represents less than five hundred acres.

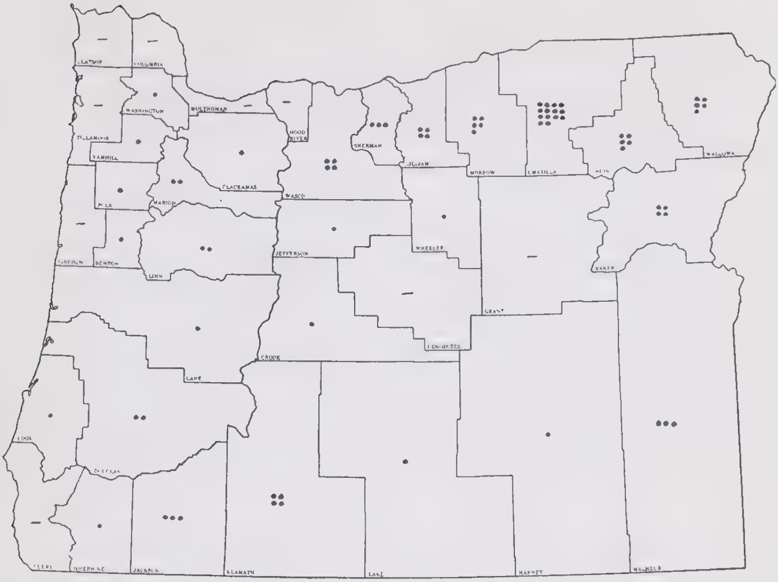

Fig. 3. Barley acreage in Oregon, averages for 1918-1923 inclusive. Each dot represents one thousand acres; each dash represents less than five hundred acres.

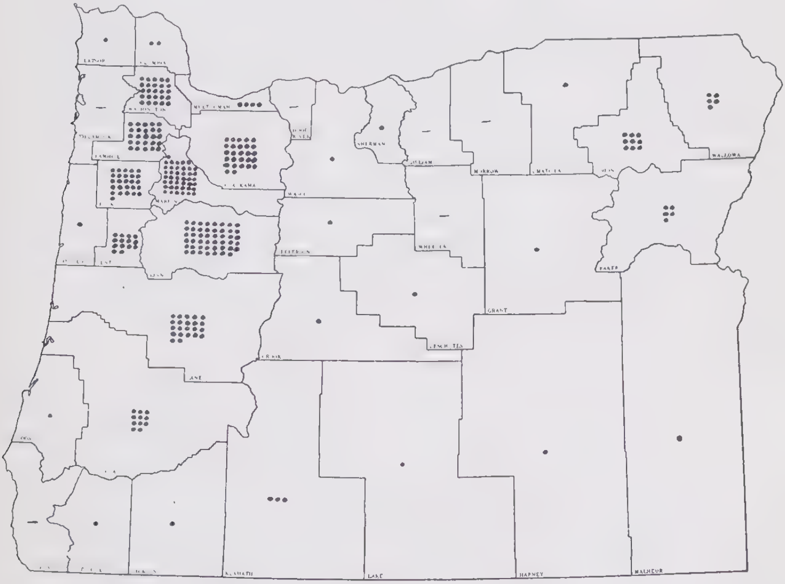

Fig. 4. Oat acreage in Oregon, averages for 1919-1923 inclusive. Each dot represents one thousand acres; each dash represents less than five hundred acres.

$17.34, of oats $14.26; and of spring wheat $12.16. In yield, however, barley ranked first for the state, slightly exceeding the average yield of winter wheat in pounds per acre. In the counties east of the Cascades barley also exceeded the yield of winter wheat, though in value per acre winter wheat was slightly higher, because of the higher average price per pound for wheat.

In Gilliam, Morrow, Sherman, Umatilla, and Union counties the five-year average yield of winter wheat exceeded that of spring barley, which ranked second in yield. In these five counties practically all the winter wheat is grown after fallow, and the barley generally follows a grain crop.

The distribution of winter wheat, spring wheat, barley, and oats in Oregon is graphically shown in Figures 1 to 4 inclusive.

## WHEAT

Wheat is the most important farm crop grown in Eastern Oregon. Both winter and spring varieties are raised. The total acreage devoted to winter and spring wheat in Oregon is shown in Table I.

From the standpoint of acreage, spring wheat is the third cereal of importance in the state, being considerably exceeded by the acreage in winter wheat, and also by the number of acres devoted to growing oats. In several counties of the state, spring wheat is an important crop. The average annual acreage for the five-year period, 1919 to 1923, inclusive, exceeded 15,000 acres in each of seven counties: Linn, Gilliam, Jefferson, Morrow, Umatilla, Union, and Wallowa.

In the following Eastern Oregon counties, the average total acreage of spring wheat for the past five years exceeded that sown to winter wheat: Baker, Crook, Deschutes, Grant, Harney, Hood River, Jefferson, Klamath, Lake, Malheur, Union, and Wallowa. Jefferson county's acreage was highest, averaging 31,130 acres. Union county was second with an average acreage of 28,025.

The average acre yield of spring wheat exceeded that of winter wheat in the following six counties of Eastern Oregon, where a large part of the crop was grown under irrigation: Baker, Crook, Deschutes, Harney, Klamath, and Lake. In the other twelve counties, higher average acre yields were obtained from winter wheat.

In Eastern Oregon, most of the winter wheat is grown after fallow and a large part of the spring wheat is grown after a grain crop the preceding year. In sections where irrigation is practiced, much more spring wheat is grown than winter wheat.

On the branch station at Moro the ten-year average yield of Turkey winter wheat, C. I. No. 1571, was 32.5 bushels per acre when grown after summer fallow. Baart spring wheat during the same period averaged 25.5 bushels per acre after summer fallow. For the six-year period during which it has been grown, 1918 to 1923, inclusive, Hybrid 128 winter wheat averaged 34.8 bushels per acre in yield at Moro, and Federation spring wheat averaged 28.5 bushels per acre. When both are grown after corn or after peas, spring wheat has produced as high acre yields as winter wheat on the Moro station.

**Experiment station results.** Experiments to determine the highest-yielding wheat varieties for Eastern Oregon have been in progress for a number of years at the branch stations* at Moro in Sherman county, at Union in Union county, and at Burns in Harney county. Before the establishment of these stations, the most important varieties of spring wheat commercially grown were Pacific Bluestem, Little Club, and Red-chaff. At the present time these varieties have been largely supplanted by Federation, Hard Federation, and Baart. The yields of these varieties in the varietal trials at Moro and Burns, for the years 1918 to 1923, inclusive, are shown in Table II.

Fig. 5. General view of spring-grown experimental plots on Sherman County Branch Station, Moro.

Fig. 6. General view of experimental farm, Eastern Oregon Branch Station, Union.

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*The branch station at Moro is maintained cooperatively by the State of Oregon, through the Oregon Agricultural Experiment Station, and the United States Department of Agriculture, through the Office of Cereal Investigations of the Bureau of Plant Industry. The branch station at Burns was also cooperatively maintained by these same agencies from 1911 to 1920. Since July 1, 1920 the station at Burns has been maintained solely from state funds.

The yields at Moro were obtained under dry-farming conditions on land left fallow the previous year. The average annual precipitation at Moro during this period was 11.37 inches. The yields at Union were obtained on black silt loam soil typical of the southern portion of the Grande Ronde Valley under subirrigated conditions. The average annual precipitation at Union is 14.03 inches. The yields at Burns were obtained under irrigated and dry-land conditions with fallow preceding the wheat on dry land and oats preceding it under irrigation. The average annual precipitation at the branch station at Burns for the four-year period was 8.68 inches.

TABLE II. YIELDS OF SPRING WHEAT IN BUSHELS PER ACRE AT MORO AND BURNS, OREGON, FOR THE YEARS 1918 TO 1923, INCLUSIVE

Yields at Moro

| C. I. No. | Variety | 1918 | 1919 | 1920 | 1921 | 1922 | 1923 | Average |
|---|---|---|---|---|---|---|---|---|
| 1697 | Baart | 14.9 | 24.2 | 22.4 | 23.5 | 19.5 | 37.0 | 23.6 |
| 4066 | Little Club | 18.0 | 23.0 | 20.0 | 22.2 | 17.5 | 31.5 | 22.0 |
| 4067 | Pacific Bluestem | 13.0 | 23.7 | 18.2 | 21.5 | 20.5 | 33.9 | 21.8 |
| 4158 | Marquis | 15.0 | 22.7 | 19.2 | 19.7 | 17.0 | 34.9 | 21.4 |
| 4733 | Hard Federation | 21.3 | 28.7 | 25.9 | 29.0 | 21.0 | 40.8 | 27.8 |
| 4734 | Federation | 21.0 | 28.7 | 24.5 | 29.9 | 21.3 | 45.3 | 28.5 |
| 4981 | White Federation | ...... | 28.3 | 23.7 | 27.7 | 24.2 | 41.0 | 29.0 |

Yields at Burns

| C. I. No. | Variety | Dry-land |  |  |  |  | Irrigation |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | 1920 | 1921 | 1922 | 1923 | Average | 1920 | 1921 | 1922 | 1923 | Average |
| 1697 | Baart | 36.5 | 28.3 | 27.4 | 34.5 | 31.7 | 65.0 | 36.4 | ...... | ...... | ...... |
| 3663 | Dicklow | ...... | ...... | ...... | ...... | ...... | 77.1 | 45.4 | 47.1 | 74.8 | 61.1 |
| 4158 | Marquis | 28.5 | 21.0 | ...... | 28.2 | 25.9 | 64.0 | 36.0 | 30.8 | 51.8 | 45.7 |
| 4734 | Federation | 31.0 | 23.8 | 25.3 | 39.0 | 29.8 | 82.9 | 50.9 | 50.3 | 73.5 | 64.4 |
| 4733 | Hard Federation | 21.2 | 25.0 | 21.0 | 34.1 | 25.4 | 55.1 | 28.5 | 25.6 | 48.1 | 39.3 |
| 4981 | White Federation | ...... | ...... | 20.3 | 35.4 | ...... | ...... | 23.3 | 27.7 | 49.7 | 33.6 |
| 4067 | Pacific Bluestem | 31.9 | 25.2 | ...... | ...... | ...... | 57.5 | 42.7 | ...... | ...... | ...... |

**Results at Moro.** Table II gives the yields of six spring wheat varieties grown at Moro after fallow for the six-year period, 1918 to 1923, inclusive, and seven varieties for the five-year period, 1919 to 1923, inclusive. The highest average yield obtained was from Federation, 28.5 bushels per acre for the six-year period. The yields of the three Federation wheats, Federation, Hard Federation, and White Federation, are quite similar, the average for the five-year period being only slightly higher for Federation and Hard Federation than for White Federation. Each of these three varieties considerably outyielded the next highest yielding spring wheat, Baart. Federation averaged 4.9 bushels and Hard Federation 4.2 bushels per acre more. Baart for this period slightly exceeded the yield of Marquis, Pacific Bluestem, and Little Club.

**Results at Burns.** Table II also gives the yields of seven wheat varieties grown at the Burns Branch Station for the years 1920 to 1923, inclusive, on both dry and irrigated land. Three varieties, Baart, Federation, and Hard Federation, were grown for the four-year period on dry land, and four varieties, Dicklow, Marquis, Federation, and Hard Federation, were grown for the four-year period under irrigation.

As a dry-land wheat, Baart produced the highest average yield, with Federation second and Hard Federation third. The average yield of Baart exceeded the yield of Federation nearly two bushels per acre for the four-year period.

*Federation yields more than Marquis.* Under irrigation, the highest yield was obtained from the Federation variety, Dicklow ranking second, and Marquis third. Federation exceeded the average yield of Dicklow by 3.2 bushels per acre. In a fertilizer experiment at Burns for the years 1921 to 1923, inclusive, the average yields of Federation wheat for the various treatments ranged from 59.6 to 75.7 bushels per acre.

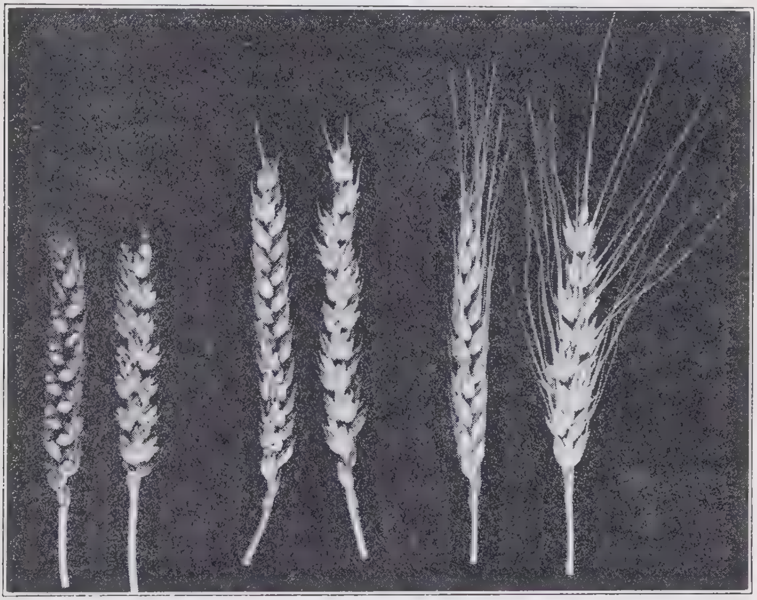

Fig. 7. Heads (from left to right) of Hard Federation, Pacific Bluestem, and Baart spring wheat varieties.

**Results at Union.** The Hard Federation and White Federation wheats were tried at the Union Branch Station in 1922. In 1923 Federation and Onas, a hybrid with Federation as one of the parents, were added. The yields obtained from Hard and White Federation in 1922 were considerably exceeded by Pacific Bluestem and Little Club. In 1923, the following results were obtained from a varietal trial in duplicate tenth-acre plots:

| | Bushels per acre |
|---|---|
| Onas | 59.9 |
| Federation | 58.6 |
| White Federation | 44.4 |
| Baart | 43.9 |
| Pacific Bluestem | 42.7 |
| Hard Federation | 38.8 |
| Little Club | 28.3 |
| Dicklow | 27.7 |

**Trials by farmers.** Comparative yield trials with spring wheat have been conducted for a number of years by farmers in various counties of Eastern Oregon. Many letters have been received by the Moro Branch Station from farmers regarding the performance of the Federation wheats in comparison with commonly-grown spring wheat varieties. The results for 1923 have been summarized by the county agents in several counties where demonstration trials have been in progress between Federation, Hard Federation, and other spring wheat varieties.

*Umatilla county.* In Umatilla county in 1923 approximately 1500 acres of Hard Federation spring wheat were grown by twenty-four farmers. Sixteen of these farmers reported yields of from two to ten bushels per acre higher than other spring wheats grown under similar conditions, the average increased yield being about five bushels per acre. No farmers reported lower yields from Hard Federation than from other spring wheat varieties except that one grower reported that Federation slightly exceeded the yield of Hard Federation.

Federation wheat was grown in Umatilla county from fall sowing by five farmers, and from spring sowing by four farmers. Two hundred and thirty-five acres were fall sown and 560 spring sown. Under similar conditions, the fall-sown Federation wheat exceeded by ten bushels to the acre the yield of the highest yielding winter wheat. Seven thousand acres of Federation wheat were sown in Umatilla county in the fall of 1923. Federation is a spring wheat, and too much confidence should not be placed in its performance for a short period of time as a fall-sown variety. Further trials will be necessary to determine in just what localities, if any, in Eastern Oregon Federation can safely be fall sown.

*Union county.* In Union county two hundred farmers grew Hard Federation wheat in 1923, more than 5000 acres being sown. Twenty of these farmers reported to the county agent that Hard Federation exceeded the yield of other spring wheats grown under similar conditions. Yields of from twenty to fifty bushels per acre were obtained with an average of about twenty-five bushels for the county. No farmer who grew the Hard Federation wheat reported a yield lower than that obtained from other spring wheat varieties. No Federation wheat was grown in Union county by farmers in 1923, but demonstration trials will be carried on in 1924 from both fall and spring sowing.

*Wallowa county.* In Wallowa county there were approximately 100 acres of Federation wheat grown by two farmers under irrigation. Yields of thirty and forty-five bushels per acre were obtained. Both of these farmers reported higher yields from Federation wheat than from other spring wheat varieties. About 1000 acres of Hard Federation were grown in Wallowa county by thirty-five farmers. The yields obtained ranged from twenty to forty bushels per acre, averaging about thirty bushels. Ten farmers from whom reports were received reported that the yields of Hard Federation were higher than those obtained from other spring wheats grown under similar conditions.

*Baker county.* More than 1000 acres of Federation wheat were grown under irrigation in Baker county by forty-five farmers. Thirty of the farmers from whom reports were received obtained higher yields from Federation than from other wheats grown under similar conditions, the average being about seven bushels per acre more than for any other spring wheat. One farmer reported a lower yield from Federation than from Dicklow.

The Hard Federation variety was grown under both irrigated and dry-land conditions in this county by twenty-six farmers. One farmer reported an equal yield from Federation and Hard Federation, and twenty-five farmers reported higher yields from Hard Federation than from other spring wheats.

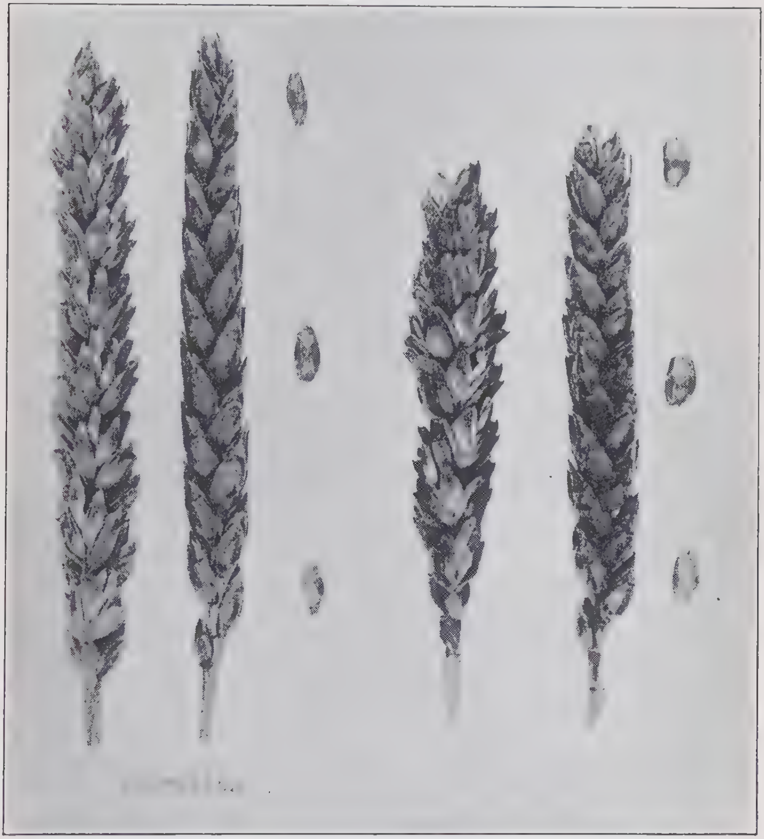

Fig. 8. Heads of Federation and Hard Federation spring wheats.

*Malheur county.* Five hundred acres of Federation spring wheat were grown in Malheur county under irrigation by about thirty farmers. In twelve carefully conducted demonstration trials by the county agent, this wheat averaged fifty-six bushels per acre in yield or about fifteen bushels per acre higher than the average of other spring wheats with which it was compared. No growers reported lower yields from the Federation variety than from other spring wheats. In these trials the wheat was compared with Jenkin, Baart, and Dicklow—all under irrigation.

*Deschutes county.* In Deschutes county fourteen farmers grew Federation wheat, about one-half of the acreage being under irrigation and one-half on dry land. Twelve of these farmers from whom reports were received stated that higher yields were obtained from this wheat than from other spring wheat varieties.

*Crook county.* Twenty-four farmers in Crook county grew 408 acres of Federation wheat under irrigation. Reports received from eighteen of these farmers stated that the yields obtained from Federation wheat ranged from twelve to fourteen bushels per acre higher than that obtained from other spring wheat varieties grown under similar conditions. Three farmers in this county grew Hard Federation and reported an average yield of nine bushels per acre higher than from other spring wheats.

**The Federation varieties.** The three Federation spring wheat varieties—Federation, Hard Federation, and White Federation—are of Australian origin. The first sowing of these varieties in the United States was made at the branch experiment station at Moro in 1916 from small quantities of seed furnished to the United States Department of Agriculture by the Department of Agriculture of New South Wales, Australia. They were grown in short rows in the plant breeding nursery at Moro in 1916. Because of their promising appearance, seed was increased as rapidly as possible. Two of the varieties were included in comparative trials in nursery rows in 1917 and in larger plots the following year.

Because of their high yields in the station trials in 1918, a limited quantity of seed of Hard Federation and Federation was distributed in 1919 to farmers for further trial. The results secured by farmers in 1919 and the results on the station justified a further distribution of these two varieties to different sections of the state. In several localities in Eastern Oregon, these varieties are now commercially established, and as the preceding reports from farmers indicate, these varieties have proved so promising that they will probably soon replace all other spring-sown wheats in most parts of Eastern Oregon. The varieties have also given good results in other western states.

Each of the varieties is beardless, and the kernels are white. Hard Federation and White Federation mature earlier than Federation and have harder kernels of a slightly better milling quality. The heads of Federation and Hard Federation are brown, and those of White Federation are white. The varieties all have short, stiff straw and do not shatter very readily. They are spring varieties. Federation is more winter hardy than Hard Federation or White Federation but not sufficiently hardy to be recommended for general fall sowing in Eastern Oregon. One year's results in Umatilla county indicate that Federation might perhaps advantageously replace Jenkin and Redchaff, two spring wheats now grown from fall sowing in that county. Numerous hybrids have been made at the Moro Station between the Federation wheats and present commercial winter wheats in order to produce a hardy winter wheat with other desirable qualities now possessed by the Federation varieties. A large number of pure-line selections have also been made from these wheats, especially Hard Federation, with the hope of further improving their yield and quality.

Heads and kernels of Federation, Hard Federation, Baart, and Pacific Bluestem spring wheats are shown in Figs. 1, 2, and 3.

**Milling and baking data.** The two most important considerations in influencing the farmer's decision as to what wheat variety to grow are acre yield and market price. The milling quality of wheat should be an important factor in determining market price. During recent years in the Pacific Northwest, however, wheats of poor milling quality have brought nearly as high, and in some cases a higher, price on the market than high-protein, good milling wheats, so that more attention has been paid by farmers to quantity rather than quality production. The branch experiment stations in Eastern Oregon have been concerned in improving the quality of wheat as well as in producing high yielding varieties. Milling and baking trials are made every year by the Section of Milling

Fig. 9. Governor Walter M. Pierce in a field of Federation wheat which yielded 82.2 bushels per acre on irrigated land at the Harney Valley Branch Station, Burns, 1923.

Investigations, Grain Division, Bureau of Agricultural Economics, of the United States Department of Agriculture on a large number of wheat varieties grown at the Moro Branch Station. Similar milling and baking trials were conducted on wheats grown at the Burns Branch Station from 1918 to 1922, inclusive.

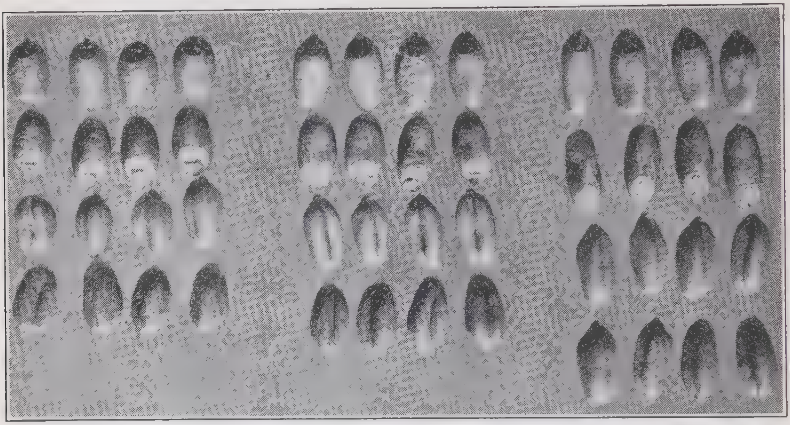

Fig. 10. Kernels (left to right) of Hard Federation, Pacific Bluestem, and Baart spring wheats.

*Hard Federation excellent milling wheat.* In Table III are given some important milling and baking characteristics of five spring and two commercially-grown winter wheat varieties for the years 1918 to 1923, inclusive, together with the annual and average yields of these varieties for this period. These varieties were grown at Moro under identical soil and climatic conditions. Of the varieties listed in this table, Hard Federation and Marquis rank highest as milling wheats, the average protein content, loaf volume, and score for loaf texture and color being higher than those of the other varieties.

It will be noted from this table that Hard Federation compares very favorably with Marquis, which is considered one of the best milling wheats grown commercially. The bushel weight of Hard Federation every year considerably exceeded that of Marquis, and weight per bushel is an important factor in determining grade and price.

It will also be noted from this table that Federation appears to be a somewhat better milling wheat than Baart, its average loaf volume and the percentage of flour made from the wheat being slightly higher. In average weight per bushel, Baart exceeded Federation as it also did in its average score for loaf color. The acre yield at Moro of Federation for the six years was nearly five bushels higher than that of Baart, while at Burns on dry land Baart was higher in acre yield by 1.9 bushels.

The spring wheats, though averaging less in acre yield, were superior in most respects to either of the two winter wheats for breadmaking, Hybrid 128 making an especially poor showing from a milling and baking standpoint.

In Table IV milling and baking data are given for five wheat varieties grown under irrigation at Burns for the years 1920 to 1922, inclusive.

### TABLE III. MILLING AND BAKING DATA FOR WHEAT VARIETIES GROWN AT MORO, OREGON, UNDER SIMILAR CONDITIONS FOR THE YEARS 1918 TO 1923, INCLUSIVE

| Variety and Cereal Investigations Number | Year | Acre yield | Bushel weight | Protein | Flour | Loaf volume | Loaf texture | Loaf color |
|---|---|---|---|---|---|---|---|---|
| | | *bu.* | *lbs.* | % | % | *c.c.* | % | % |
| Baart (1697) | 1918 | 14.9 | 57.0 | 15.8 | 68.6 | 2250 | 89.5 | 87.0 |
| | 1919 | 24.2 | 61.6 | 10.5 | 71.8 | 2000 | 90.5 | 94.5 |
| | 1920 | 22.4 | 59.1 | 12.7 | 64.7 | 1990 | 88.0 | 92.5 |
| | 1921 | 23.5 | 55.6 | 13.4 | 67.3 | 2080 | 91.0 | 90.5 |
| | 1922 | 19.5 | 55.4 | 11.2 | 67.7 | 2020 | 86.0 | 90.8 |
| | 1923 | 37.0 | 61.1 | 13.5 | 70.1 | 2130 | 87.5 | 91.0 |
| Average | | 23.6 | 58.3 | 12.9 | 68.3 | 2078 | 88.8 | 91.1 |
| Marquis (4158) | 1918 | 15.0 | 55.3 | 16.6 | 71.7 | 2600 | 91.5 | 88.5 |
| | 1919 | 22.7 | 52.4 | 15.4 | 69.9 | 2280 | 91.5 | 89.0 |
| | 1920 | 19.2 | 51.9 | 16.8 | 68.7 | 2140 | 90.0 | 86.5 |
| | 1921 | 19.7 | 54.6 | 14.0 | 68.9 | 2190 | 92.0 | 92.0 |
| | 1922 | 17.0 | 52.4 | 15.9 | 73.2 | 2000 | 85.0 | 88.5 |
| | 1923 | 34.9 | 60.4 | 13.9 | 73.7 | 2250 | 89.5 | 90.0 |
| Average | | 21.4 | 54.5 | 15.4 | 71.0 | 2243 | 89.9 | 89.1 |
| Hard Federation (4733) | 1918 | 21.3 | 59.8 | 15.2 | 72.4 | 2280 | 93.0 | 92.0 |
| | 1919 | 28.7 | 56.5 | 14.3 | 71.9 | 2110 | 91.0 | 92.0 |
| | 1920 | 25.9 | 55.2 | 13.7 | 71.3 | 1940 | 92.0 | 92.0 |
| | 1921 | 29.0 | 60.9 | 12.3 | 69.9 | 2090 | 90.8 | 93.5 |
| | 1922 | 21.0 | 54.3 | 14.4 | 69.7 | 2110 | 90.5 | 94.0 |
| | 1923 | 40.8 | 60.7 | 14.0 | 71.8 | 2260 | 90.8 | 93.5 |
| Average | | 27.8 | 57.9 | 14.0 | 71.2 | 2132 | 91.4 | 92.8 |
| Federation (4734) | 1918 | 21.0 | 56.7 | 14.3 | 71.5 | 2200 | 88.0 | 84.0 |
| | 1919 | 28.7 | 54.8 | 13.6 | 68.5 | 2120 | 88.0 | 91.0 |
| | 1920 | 24.5 | 54.9 | 13.2 | 70.4 | 2080 | 91.5 | 88.0 |
| | 1921 | 29.9 | 56.1 | 12.7 | 68.5 | 1930 | 88.3 | 86.0 |
| | 1922 | 21.3 | 52.4 | 14.0 | 65.5 | 2180 | 84.0 | 91.8 |
| | 1923 | 45.3 | 60.4 | 10.8 | 70.5 | 2230 | 91.3 | 89.8 |
| Average | | 28.5 | 55.9 | 13.1 | 69.2 | 2123 | 88.3 | 88.4 |
| Pacific Bluestem (4067) | 1918 | 13.0 | 56.1 | 15.7 | 70.7 | 2090 | 86.5 | 84.0 |
| | 1919 | 23.7 | 51.0 | 15.6 | 66.1 | 1740 | 85.0 | 87.0 |
| | 1920 | 18.2 | 51.0 | 15.3 | 58.6 | 2220 | 89.5 | 86.0 |
| | 1921 | 21.5 | 54.4 | 14.4 | 63.4 | 1980 | 89.5 | 89.0 |
| | 1922 | 20.5 | 55.1 | 14.8 | 67.3 | 1790 | 84.0 | 73.5 |
| | 1923 | 33.9 | 60.0 | 12.9 | 71.2 | 2030 | 87.5 | 90.3 |
| Average | | 21.8 | 54.6 | 14.8 | 66.2 | 1975 | 87.0 | 85.0 |
| Kharkov | 1918 | 26.2 | 60.0 | 11.4 | 68.8 | 2100 | 89.0 | 89.0 |
| | 1919 | 40.0 | 61.8 | 10.7 | 71.3 | 1760 | 88.5 | 92.0 |
| | 1920 | 33.2 | 58.1 | 12.2 | 71.5 | 1910 | 88.5 | 88.0 |
| | 1921 | 40.1 | 61.7 | 8.0 | 71.9 | 1820 | 90.5 | 92.5 |
| | 1922 | 17.1 | 56.1 | 13.2 | 72.4 | 1910 | 86.0 | 85.8 |
| | 1923 | 35.3 | 60.1 | 9.7 | 71.5 | 1930 | 84.3 | 88.8 |
| Average | | 32.0 | 59.6 | 10.9 | 71.2 | 1905 | 87.8 | 89.4 |
| Hybrid 128 (4512) | 1918 | 26.5 | 57.0 | 13.6 | 69.5 | 1970 | 87.5 | 89.5 |
| | 1919 | 40.6 | 59.7 | 11.7 | 73.3 | 1730 | 87.5 | 86.5 |
| | 1920 | 36.8 | 55.4 | 12.3 | 63.1 | 1810 | 87.5 | 88.5 |
| | 1921 | 43.0 | 59.8 | 12.7 | 67.0 | 1670 | 82.5 | 85.5 |
| | 1922 | 21.2 | 53.9 | 13.7 | 69.9 | 1610 | 84.0 | 85.5 |
| | 1923 | 40.5 | 58.5 | 10.2 | 70.1 | 1820 | 79.3 | 85.8 |
| Average | | 34.8 | 57.4 | 12.4 | 68.8 | 1768 | 84.7 | 86.9 |

These data show that Hard Federation and White Federation are satisfactory milling wheats when grown under irrigation, averaging higher in loaf volume than Marquis. There did not appear to be a great deal of difference in the milling and baking values of Dicklow and Federation when grown under irrigation at Burns. In other experiments by the United States Department of Agriculture, Federation has proved superior to Dicklow in milling quality when grown under irrigation.[1]

TABLE IV. MILLING AND BAKING DATA FOR WHEAT VARIETIES GROWN AT BURNS, OREGON, UNDER IRRIGATION FOR THE YEARS 1920 TO 1922, INCLUSIVE

| Variety and Cereal Investigations Number | Year | Acre yield | Bushel weight | Protein | Flour | Loaf volume | Loaf texture | Loaf color |
|---|---|---|---|---|---|---|---|---|
| | | *bu.* | *lbs.* | % | % | *c.c.* | % | % |
| Dicklow (3663) | 1920 | 77.1 | 57.2 | 10.1 | 71.9 | 1750 | 84.0 | 89.5 |
| | 1921 | 45.4 | 59.0 | 9.6 | 72.5 | 2090 | 89.0 | 92.0 |
| | 1922 | 47.1 | 58.6 | 11.2 | 71.8 | 1980 | 91.3 | 91.8 |
| Average | | 56.5 | 58.3 | 10.3 | 72.1 | 1940 | 88.1 | 91.1 |
| Pacific Bluestem (4067) | 1920 | 57.5 | 57.7 | 12.2 | 70.3 | 1580 | 83.0 | 88.0 |
| | 1921 | 42.7 | 56.8 | 12.8 | 68.9 | 1825 | 84.4 | 84.3 |
| Average | | 50.1 | 57.3 | 12.5 | 69.6 | 1703 | 83.7 | 86.2 |
| Marquis (4158) | 1920 | 64.0 | 59.8 | 13.1 | 71.2 | 2020 | 90.5 | 92.0 |
| | 1921 | 36.0 | 61.4 | 11.2 | 76.6 | 2110 | 86.5 | 91.5 |
| | 1922 | 30.8 | 61.1 | 13.7 | 77.6 | 2125 | 90.0 | 92.0 |
| Average | | 43.6 | 60.8 | 12.7 | 75.1 | 2085 | 89.0 | 91.8 |
| Hard Federation (4733) | 1920 | 55.1 | 58.7 | 14.5 | 71.3 | 2030 | 89.0 | 90.5 |
| | 1921 | 28.5 | 60.6 | 11.6 | 73.0 | 2120 | 84.5 | 92.0 |
| | 1922 | 25.6 | 58.6 | 13.6 | 71.1 | 2180 | 88.3 | 87.5 |
| Average | | 36.4 | 59.3 | 13.2 | 71.8 | 2110 | 87.3 | 90.0 |
| Federation (4734) | 1920 | 82.4 | 58.5 | 11.8 | 73.5 | 1930 | 86.0 | 90.0 |
| | 1921 | 50.9 | 61.5 | 10.5 | 73.8 | 2000 | 87.0 | 88.0 |
| | 1922 | 50.3 | 59.7 | 9.5 | 69.0 | 2050 | 87.3 | 88.5 |
| Average | | 61.2 | 59.9 | 10.6 | 72.4 | 1993 | 86.8 | 88.8 |
| White Federation (4981) | 1921 | 23.3 | 59.5 | 10.2 | 75.9 | 2130 | 88.5 | 92.5 |
| | 1922 | 27.7 | 59.7 | 14.3 | 73.1 | 2290 | 89.8 | 90.0 |
| Average | | 25.5 | 59.6 | 12.3 | 74.5 | 2210 | 89.2 | 91.3 |

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[1] Farmers' Bulletin No. 1301, U. S. Department of Agriculture.

That Hard Federation wheat is likely to be in demand for commercial milling is indicated by the following extract from a letter from Mr. E. O. McCoy of the Wasco Warehouse Milling Company, who operates one of the largest flour mills in Oregon.

> The Dalles, Oregon, Jan. 12, 1924.
>
> Dear Sir:
>
> Replying to your letter of January 11 regarding Hard Federation wheat, we advise that we have so far milled only a limited quantity of this wheat, but what experience we have had shows that the results have been very satisfactory for making certain quality of flour.
>
> In milling we class the Hard Federation in the same family that we do Bluestem and Baart wheat. The Hard Federation is fully equal to the best Bluestem and Baart that we have been able to obtain anywhere in Oregon, Washington, or Idaho. About half of the wheat we grind is wheat of this family and we use it for making fancy family flour and for blending with eastern hard wheats for extra bakers' flour. By using Hard Federation as a blend with hard wheats, we secure loaf volume, texture of loaf, and color that is much more satisfactory than when using the eastern wheat alone. . . As far as our experience goes, it is a better wheat for milling than any Marquis we have been able to obtain in either Oregon or Washington.
>
> We consider it highly important that a wheat of the nature of Hard Federation be raised in our immediate territory, particularly in Sherman county, as the soils of that county are adapted to raising strong wheat. For the past two or three years, and at the present time, we are having to ship most of our strong soft wheats from Idaho, which is more or less inconvenient to the mill, and is sending money out of this state.
>
> As this wheat has good yielding qualities, we highly recommend it as a milling wheat, and from what experience we have had would say that it would also bring a premium price along with Bluestem and Baart. If it showed better strength, as it seems to this season, it would bring even better prices than either of those two wheats.
>
> Yours very truly,
>
> WASCO WAREHOUSE MILLING CO.,
>
> E. O. McCOY.

**Time and rate of sowing spring wheat.** All results on the branch experiment stations in Eastern Oregon emphasize the necessity of sowing spring wheat early in the spring. When sown late, low yields and poor quality wheat usually result, because of late maturity and consequent drought injury.

The rate of sowing for spring wheat should vary somewhat for different varieties, those with large kernels, like Baart, requiring thicker seeding than those with small kernels like Marquis. Some varieties, too, tiller or stool less than others and therefore should be sown at a heavier rate. The rate of sowing also should vary with locality and soil type, the sections of higher rainfall and heavier soil types requiring thicker seeding than the areas of light rainfall and light soils. The rate of sowing, also, should vary according to method of seed treatment for smut, seed treated with copper carbonate requiring a thinner rate than that treated with formalin or bluestone.

Experiments at Moro have shown that on the average the best rate to sow spring wheat when the seed has been treated with formalin or bluestone, is about one bushel per acre. To sow at the rate of one bushel of dry seed per acre, the drill will have to be set to sow at the rate of about five and one-half pecks per acre of treated seed to allow for the increase in volume of wet seed. Only one year's results are available at Moro for seed of Baart and Hard Federation spring wheats treated with copper carbonate and sown at varying rates. In 1923, the highest yields of Baart were obtained from the four-peck sowing, and identical yields were obtained from Hard Federation sown at the rate of 2, 3, and 4 pecks per acre. Lowest yields from both varieties were obtained from the 7 and 8 peck rates.

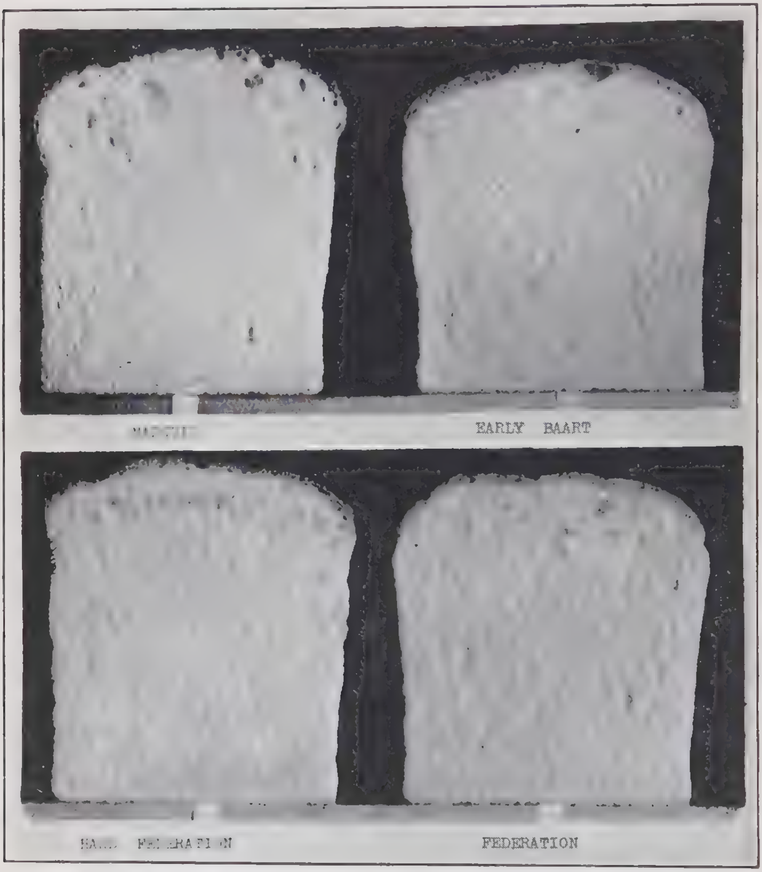

Fig. 11. Cross-section of loaves of bread made from four spring wheat varieties of the crop of 1921 grown at the Sherman County Branch Station, Moro.

Results at the branch stations show that satisfactory smut control in spring wheat is secured by using the dry copper carbonate method. Because of less seed injury and the saving of seed this method is recommended for treating wheat. For treating barley and oats, the formaldehyde or the bluestone treatment should be used.

**Seed bed preparation.** Wheat, like the other small grains, requires a good firm seed bed for best results. Where wheat is to follow another grain crop, the land should be fall plowed if possible and left rough over winter. A disk or spring-tooth harrowing followed once or twice with a spike-tooth harrow will generally put the soil in ideal condition. If spring plowed, the soil should be firmed with a packer or disk harrow with disks set nearly straight, followed with the spike-tooth or smoothing harrow as many times as may be necessary, once usually sufficing for lighter soil types.

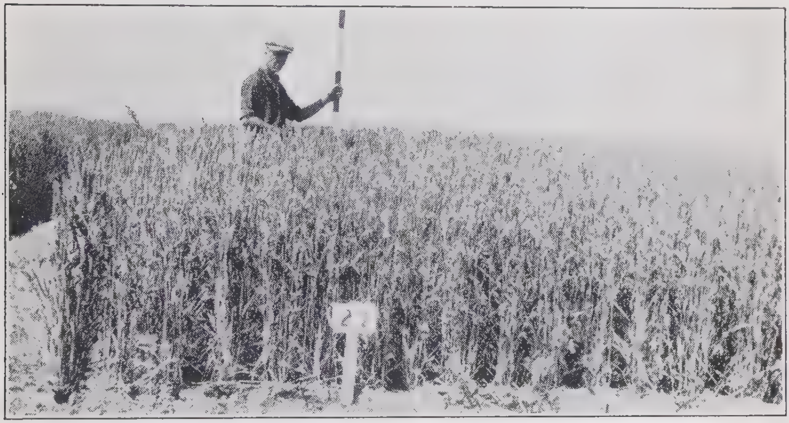

Fig. 12. A plot of Federation spring wheat on the Harney Valley Branch Station in 1923 that yielded 90.6 bushels per acre on irrigated land.

When spring wheat is sown on ground left fallow the previous year, it is generally necessary to use the disk or spring-tooth harrow once and follow with the spike-tooth harrow.

When spring wheat is sown after a cultivated crop like corn, peas or potatoes, plowing generally is not necessary. A double disking and harrowing in most cases will be sufficient cultivating to make a good seed bed.

It is a good practice, especially where weeds are troublesome, to harrow the ground once with a spike-tooth harrow four or five days after sowing spring wheat. Harrowing the crop after it is up is not advisable.

## BARLEY

The second most important cereal in Eastern Oregon is barley, though the acreage and production of this crop for the entire state are considerably exceeded by those of oats. Table I shows the average acreage and production of barley in Oregon, by counties, for the five-year period, 1919 to 1923, inclusive.

Both winter and spring barleys are grown in Eastern Oregon. Because of lack of winter-hardiness, the areas on which winter barley is grown are limited to a very few localities where the winters are mild or where the snow covering generally affords protection to the crop during the winter months.

As is shown in Table I, the average five-year farm yield of barley, in pounds per acre, exceeded that of spring wheat or oats in every county of the state. Barley also exceeded the average yield of winter wheat in all counties of the state except five in Eastern Oregon where the winter wheat was grown after fallow, and three in Western Oregon, Clatsop, Polk, and Yamhill.

**Spring barley productive.** Spring barley is one of the highest yielding dry-land crops. A good spring barley generally will outyield any other spring-sown crop in Eastern Oregon. When grown after fallow in some locations it may produce higher yields than winter wheat. The oat crop is considered by farmers a better one to grow than barley on some of the wet lands in Western Oregon and in limited areas in Central Oregon where barley is sometimes injured by late spring frosts. Experiment station results, however, and the yield statistics given in Table I, strongly indicate that barley should more generally take the place of spring wheat and oats, in nearly every county of the state. In addition to being more productive, barley is higher than oats in digestible nutrients and in proportion of grain to hull. Barley is now extensively used in Oregon for stock feed. It is successfully fed to all classes of livestock, being usually first steamed and rolled. Because of its higher acre yield, barley should further replace oats as a feed crop. When sold on the market, oats may prove more profitable to grow than barley in a few localities where there is a milling demand for the crop. The average farm price in Oregon for the past ten years for barley and oats has been about equal, though the average price for the ten-year pre-war period 1905 to 1914, was $3.33 per ton higher for oats than for barley.

**Results at Moro.** Many spring and winter barleys have been tried at the three branch experiment stations in Eastern Oregon. Experiments to determine the highest yielding barley varieties were started at Moro in 1911 and 75 varieties have been tested at that station in field plots. Winter barleys were tried in the years 1912 to 1917, inclusive. During two of these years, 1913 and 1917, all varieties of winter barley sown completely winter-killed. The highest average yields were obtained from Wisconsin winter, a six-rowed, bearded variety.

Annual and average yields of eight of the leading barley varieties grown at Moro for the eight-year period 1916 to 1923, inclusive, are shown in Table V. Of the varieties listed in this table, all are bearded types except Meloy, which is a hooded or beardless variety. Smyrna and Hannchen are two-rowed barleys. The highest yielding variety which has been in the trial during the entire twelve-year period was Mariout, its average yield being 43.9 bushels per acre. It yielded 6 percent more than Meloy for the period during which that variety was grown, 1915 to 1923, inclusive. For the eight-year period, Peruvian and Mariout have been the highest yielding varieties. Peruvian exceeded the average yield of Meloy 3.3 bushels and the average yield of Mariout was 2.5 bushels per acre more than that of Meloy.

TABLE V. ANNUAL AND AVERAGE ACRE YIELDS FOR THE LEADING SPRING BARLEY VARIETIES GROWN AT MORO, OREGON, AFTER FALLOW FOR THE YEARS 1916 TO 1923, INCLUSIVE

| Variety | C. I. No. | 1916 | 1917 | 1918 | 1919 | 1920 | 1921 | 1922 | 1923 | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|
| *Six-rowed* | | | | | | | | | | |
| Mariout | 261 | 69.3 | 45.4 | 29.0 | 40.2 | 39.2 | 41.7 | 37.3 | 59.5 | 45.2 |
| Beldi | 190 | 59.9 | 35.8 | 21.5 | 38.1 | 40.6 | 42.1 | 27.3 | 51.5 | 39.6 |
| Peruvian | 935 | 77.5 | 43.7 | 24.1 | 44.4 | 39.3 | 43.4 | 28.2 | 66.5 | 45.9 |
| Trebi | 936 | 95.8 | 27.5 | 24.2 | 47.3 | 28.5 | 34.4 | 24.4 | 70.0 | 44.0 |
| Coast | 2301 | 67.1 | 40.6 | 18.8 | 43.1 | 31.0 | 38.4 | 24.2 | 62.1 | 40.7 |
| *Two-rowed* | | | | | | | | | | |
| Hannchen | 531 | 68.3 | 36.8 | 25.0 | 39.8 | 28.5 | 33.4 | 19.8 | 61.5 | 39.1 |
| Smyrna | 658 | 71.8 | 38.0 | 22.8 | 35.0 | 30.4 | 37.7 | 18.6 | 52.9 | 38.4 |
| *Hooded* | | | | | | | | | | |
| Meloy | 1178 | 63.9 | 47.5 | 18.5 | 52.5 | 36.2 | 34.8 | 28.9 | 58.8 | 42.6 |

**Results at Union.** Many spring barley varieties have been tried at the Union Branch Station. Trebi, which has been grown since 1918, has been a consistently high yielder and a barley of splendid quality. Its nearest rival among the six-rowed varieties has been the common "Blue" or Coast variety. Of the two-rowed barleys, Hannchen and White Smyrna have been best. Both are good yielders and usually test 50 pounds or better in weight per bushel. Many new hybrid, hooded varieties have been produced at the Union Branch Station. Of these, Beardless x Blue C. is one of the most promising.

Barley grown with peas for hay and for silage has given excellent results at Union. Green weights of from 8 to 10 tons per acre have been obtained, and the ensilage has been of excellent quality.

In 1923, the following yields were obtained from a varietal test of six spring-sown barley varieties:

| | Bushels per acre |
|---|---|
| Hannchen | 96.3 |
| White Club | 93.5 |
| Trebi | 92.3 |
| Coast | 92.1 |
| Smyrna | 81.9 |
| Mariout | 80.2 |

**Results at Burns.** In Table VI are shown the annual and average yields of several spring-sown barley varieties at the Burns Branch Station on dry land after fallow for the years 1913 to 1917 and 1919 to 1921, inclusive. Four varieties were grown for this period. Trebi was grown from 1919 to 1921, inclusive. Hannchen was the highest yielding dry-land variety.

Table VII shows the annual and average yields of two varieties, Hannchen and Trebi, for the years 1919 and 1920, when grown on irrigated land; Trebi exceeded the average yield of Hannchen 3.7 bushels per acre.

TABLE VI. ANNUAL AND AVERAGE ACRE YIELDS IN BUSHELS FOR THE LEADING VARIETIES OF SPRING BARLEY GROWN AT BURNS, OREGON, ON DRY LAND AFTER FALLOW FOR THE YEARS 1913 TO 1917 AND 1919 TO 1921, INCLUSIVE

| Varieties | C. I. No. | 1913 | 1914 | 1915 | 1916 | 1917 | 1919 | 1920 | 1921 | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|
| Hannchen | 531 | 41.7 | 13.3 | 9.2 | 49.8 | 16.5 | 3.5 | 31.4 | 18.0 | 22.9 |
| Coast | 690 | 32.5 | 13.7 | 11.7 | 44.9 | 13.5 | 8.4 | 27.2 | 19.7 | 21.4 |
| Svanhals | 187 | 47.5 | 10.8 | 6.3 | 35.8 | 19.9 | 5.1 | 31.6 | 12.0 | 21.1 |
| Utah Winter | 592 | 30.2 | 8.1 | 25.2 | 31.7 | 8.9 | ------ | 26.7 | 19.7 | 21.5 |
| Trebi | 936 | ------ | ------ | ------ | ------ | ------ | 6.4 | 22.8 | 20.7 | 16.6 |

Note: The crop of 1918, destroyed by grasshoppers, was not considered in determining averages.

TABLE VII. ANNUAL AND AVERAGE ACRE YIELDS IN BUSHELS FOR TREBI AND HANNCHEN SPRING BARLEY ON IRRIGATED LAND AT THE BURNS BRANCH STATION FOR THE YEARS 1919 AND 1920

| Variety | C. I. No. | 1919 | 1920 | Average |
|---|---|---|---|---|
| Trebi | 936 | 52.0 | 67.3 | 59.7 |
| Hannchen | 531 | 49.1 | 63.0 | 56.0 |

## OATS

Spring oats are not a very important dry-land crop in Eastern Oregon. They have been largely replaced as a feed grain by spring barley. Acreage and production data for this crop are shown in Table I.

**Results at Moro.** Experiments to determine the highest yielding oat varieties have been in progress at the three branch stations in Eastern Oregon since their establishment. Annual and average yields of the leading varieties at the Moro Branch Station are shown in Table VIII. In these trials at Moro, the two varieties, Markton and Three Grain, have proved superior to all others tried. The Markton variety, a selection developed by the Moro Station, has proved to be immune to covered smut and does not have to be treated before sowing. The Three Grain variety has given unusually high yields for a midseason plump-kerneled variety. Markton is an early maturing variety with rather long, slender kernels.

TABLE VIII. ANNUAL AND AVERAGE ACRE YIELDS IN BUSHELS FOR THE LEADING OAT VARIETIES GROWN AT MORO, OREGON, AFTER FALLOW FOR THE YEARS 1916 TO 1923, INCLUSIVE

| Variety | C. I. No. | 1916 | 1917 | 1918 | 1919 | 1920 | 1921 | 1922 | 1923 | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|
| *Early* | | | | | | | | | | |
| Markton | 2053 | 102.8 | 35.3 | 30.8 | 61.6 | 44.1 | 46.7 | 32.5 | 86.3 | 55.0 |
| Richland | 787 | 86.9 | 40.3 | 36.6 | 58.4 | 35.9 | 41.6 | 26.0 | 81.3 | 50.9 |
| Kherson | 459 | 84.4 | 37.5 | 33.5 | 56.9 | 36.5 | 51.1 | 20.3 | 75.6 | 49.5 |
| Sixty Day | 165-1 | 80.3 | 37.2 | 36.9 | 52.2 | 35.9 | 45.6 | 23.5 | 80.3 | 49.0 |
| *Mid-season* | | | | | | | | | | |
| Three Grain | 1950 | 121.9 | 28.4 | 35.7 | 50.4 | 38.7 | 47.6 | 26.9 | 86.6 | 54.5 |
| Western Wonder | 1951 | 105.4 | 23.4 | 35.3 | 45.3 | 28.1 | 49.1 | 25.7 | 81.9 | 49.3 |
| Swedish Select | 134-1 | 104.7 | 26.6 | 34.1 | 50.4 | 37.5 | 36.0 | 25.7 | 76.3 | 48.9 |

**Results at Union.** The annual and average yields of several oat varieties grown at the Union Branch Station for the years 1921 to 1923, inclusive, are shown in Table IX. Of the varieties listed in the table Golden Rain produced the highest average yield. Comparable yields, however, are not available for Silvermine, a variety which has been grown on the station for a nine-year period, and the other varieties listed in Table IX, except for the year 1923.

TABLE IX. AVERAGE ACRE YIELDS OF SEVEN OAT VARIETIES GROWN AT THE UNION BRANCH EXPERIMENT STATION FOR THE YEARS 1921 TO 1923, INCLUSIVE.

| Variety | 1921 | 1922 | 1923 | Average |
|---|---|---|---|---|
| | *bu.* | *bu.* | *bu.* | *bu.* |
| Golden Rain | 68.3 | 58.4 | 126.6 | 84.5 |
| Swedish Select | 61.1 | 45.7 | 132.3 | 79.7 |
| Minnesota 295 | 52.3 | 54.5 | 128.9 | 78.6 |
| Idamine | 61.5 | 51.0 | 114.2 | 75.6 |
| Minnesota 281 | 45.3 | 40.7 | 134.3 | 73.4 |
| Improved American | 42.3 | 42.7 | 132.3 | 72.4 |
| Golden Fleece | 54.1 | 50.2 | 110.6 | 71.6 |
| Silvermine | ------ | ------ | 126.9 | ------ |

Silvermine has been the most outstanding oat in yield and quality of the varieties that have been grown for a long period of time at the Union Branch Station. It is a variety of splendid color and quality and has averaged 86.2 bushels per acre in yield for a nine-year period.

The results the past three years as shown in Table IX indicate that Golden Rain might be a close second. Unfortunately, however, this variety has a yellow color, hence it is not as popular on the market as some of the better white varieties. It is a good yielder and is worthy of further trial.

Both the Swedish Select and Improved American oats are varieties hard to excel in consistent yields and good quality. During the past three years the Improved American averaged 72.3 bushels in yield and for the past ten-year period averaged 78.7 bushels per acre.

**Results at Burns.** Table X shows the yields of the leading oat varieties tried at the Burns Branch Station on dry land. Of those grown for a ten-year period Silvermine and Rustless Selection produced the highest average yields.

In Table XI are listed the oat varieties grown at Burns on irrigated land. Only three varieties were grown for a five-year period. Of these the Rustless Selection produced the highest average yield. This variety, a selection from Sixty Day, has been a high yielding oat, but on account of its long, slender kernel and low bushel weight it is not popular on the Oregon market.

Of the varieties grown for a two-year period, Early Mountain averaged highest in yield.

TABLE X. ANNUAL AND AVERAGE YIELD OF SPRING OATS GROWN AFTER FALLOW AT THE BURNS BRANCH STATION FOR THE YEARS 1913 TO 1917 AND 1919 TO 1923, INCLUSIVE. YIELD REPORTED IN BUSHELS PER ACRE

| Variety | C. I. No. | 1913 | 1914 | 1915 | 1916 | 1917 | 1919 | 1920 | 1921 | 1922 | 1923 | 10-year Ave. | 3-yr. Ave. 1921-1923 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* |
| Silvermine | 720 | 63.7 | 14.0 | 25.0 | 43.1 | 9.3 | 6.8 | 15.6 | 53.3 | 33.3 | 69.1 | 33.3 | 51.9 |
| Rustless | 724 | 56.2 | 11.2 | 49.4 | 45.0 | 9.3 | 5.9 | 13.7 | 49.8 | 26.2 | 63.9 | 33.1 | 46.6 |
| Sixty Day | 625 | 55.0 | 19.7 | 21.9 | 42.7 | 11.2 | 6.6 | 17.0 | 34.0 | 24.1 | 63.4 | 29.5 | 40.5 |
| Swedish Select | 134 | 33.1 | 12.8 | 29.4 | 43.7 | 3.8 | 3.7 | 15.6 | 51.8 | 24.2 | 68.3 | 28.6 | 48.1 |
| Nebraska No. 21 | 841 | ------ | ------ | ------ | ------ | ------ | ------ | 18.3 | 60.0 | 27.5 | 73.5 | 44.8 | 53.7 |
| Fulghum | 708 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 44.4 | 25.0 | 80.1 | 49.8 | 49.8 |
| Golden Rain | 493 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 70.4 | ------ | ------ |
| Idamine | 1834 | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 70.5 | ------ | ------ |
| Early Mountain | ------- | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 55.6 | ------ | ------ |

Note: The crop of 1918, destroyed by grasshoppers, was not considered in determining averages.

TABLE XI. ANNUAL AND AVERAGE YIELDS OF SPRING OATS UNDER IRRIGATION AT THE BURNS BRANCH STATION FOR THE YEARS 1919 TO 1923, INCLUSIVE. YIELDS IN BUSHELS PER ACRE.

| Variety | C. I. No. | 1919 | 1920 | 1921 | 1922 | 1923 | Average for period grown | Average for 1922-1923 |
|---|---|---|---|---|---|---|---|---|
| | | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* |
| Rustless | 724 | 45.0 | 127.3 | 70.8 | 64.6 | 101.4 | 81.8 | 83.0 |
| Swedish Select | 134 | 38.0 | 117.1 | 63.5 | 61.0 | 94.4 | 74.8 | 77.7 |
| Silvermine | 720 | 35.8 | 106.8 | 61.8 | 55.8 | 103.8 | 72.8 | 79.8 |
| Nebraska No. 21 | 841 | ------ | 96.4 | 55.5 | 47.9 | 91.3 | 72.8 | 69.6 |
| Fulghum | 708 | ------ | 87.9 | 48.2 | 48.5 | 83.4 | 67.0 | 65.9 |
| Early Mountain | -------- | ------ | -------- | ------ | 86.6 | 121.4 | 104.0 | 104.0 |
| Golden Rain | 493 | ------ | -------- | ------ | 72.2 | 97.1 | 84.7 | 84.7 |
| Idamine | 1834 | ------ | -------- | ------ | 69.0 | 112.1 | 90.6 | 90.6 |

## RYE

Rye is an important crop in a few counties of Central Oregon, where it is grown for hay and grain. Because of its drought resistance, winter hardiness, and less susceptibility to damage from rodent pests, it will succeed in producing a crop under more adverse conditions than any other grain.

At the Moro Branch Station neither winter nor spring rye has proved as productive as wheat, barley, or oats. At the Burns Branch Station, Vern spring rye has been a consistently good yielder on summer-fallowed dry land. It has averaged 17 bushels per acre for the eight-year period, 1915 to 1923, inclusive.

Considerable plant breeding and varietal testing work has been done with rye at the Union Branch Station, but thus far no variety has equaled the yield of the Rosen, a bearded, winter variety.

A number of new beardless selections are under observation, and it is hoped that some of these, with further selection, will prove sufficiently productive to increase and distribute to farmers. A good beardless rye would be of immense agricultural value in many parts of Eastern and Central Oregon where this crop has proved to be the most dependable hay crop that can be grown.

## PEAS

The field pea is unquestionably a very important annual leguminous crop for Eastern Oregon conditions. All classes of livestock relish peas; in fact hogs will eat them in preference to any other grain. The following figures give the feed requirements per 100 pounds gain, resulting from the various feeding tests with fattening hogs conducted at the Union Branch Station.

| Grain | Number of tests | Feed requirements per 100 pounds of gain |
|---|---|---|
| | | *lbs.* |
| Peas | 4 | 356.5 |
| Hull-less barley | 11 | 417.6 |
| Wheat | 6 | 430.8 |
| Common barley | 7 | 434.8 |
| Rye | 1 | 440.2 |

Not only do peas show a higher feeding value for fattening hogs than barley, wheat, or rye, but they are likewise an excellent sheep feed, especially for fattening lambs. Peas have a high protein content and may be used in balancing dairy cow rations, thus furnishing home-grown protein, the most expensive part in all feed rations. The protein content of field peas is about twice that of the cereals and is equal to that of flax.

**Peas for hog pasture.** For hogging off, field peas have no equal. The following figures from trials at the Union Branch Station, while not conclusive, will give some indication as to the value of this crop for such purposes.

| Crop | No. of tests | Gains made per acre |
|---|---|---|
| | | *lbs.* |
| Field peas (green) | 1 | 480.0 |
| Field peas (ripe) | 3 | 347.0 |
| Field peas and kale | 1 | 452.0 |
| Field peas and hull-less barley | 1 | 190.0 |

When hogging off the green peas, the hogs were turned in at the time the peas had reached the green pea cooking stage, thus affording considerable green forage, which apparently gives good results as is further indicated when feeding off kale and ripe peas. The kale and peas were sown in separate plots, the hogs having access to both.

The poor showing made by peas and hull-less barley is attributed to the fact that the hogs showed such a preference for peas that they continued to search for more peas after they were gone, and it was some time before they began to work on the barley.

Hogging off peas has also given excellent results at the Moro and Burns stations.

Another important economic factor in favor of field peas is the fact that they are not only an excellent feed for livestock and a profitable crop to grow, but they are also a leguminous plant and hence nitrogen gatherers for the soil.

The Union Branch Station has grown field peas for the past fifteen years. Of the fifty or more varieties tested, the White Canada comes nearer meeting all requirements than any other variety tried. Under favorable conditions this variety will produce twenty-five bushels of matured seed per acre. As forage it will produce a splendid tonnage. This is an important factor in the production of both hay and silage.

Fig. 13. Hogs pasturing off peas at the Eastern Oregon Branch Station, Union.

At the Moro Branch Station field peas have been grown after grain and not preceded by fallow like the cereals. Several varieties have been tried, and the yields of the leading ones are given in Table XII.

As is seen from this table, the average yields of several varieties have been nearly equal, the three highest being O'Rourke, Lima, and White Canada, all white-seeded, early-maturing varieties. During the four-year period in which it has been grown, Admiral, a wrinkled, blue pea, has given yields slightly higher than those obtained from most of the other varieties.

The yield of spring wheat following peas at Moro has been only one bushel per acre lower than when the spring wheat is preceded by fallow. Winter wheat has been reduced in yield six bushels per acre after peas as compared with growing this crop after fallow. The expense of preparing a seed bed for wheat after peas is much less than after fallow or after a grain crop, as plowing is unnecessary.

At the Burns Branch Station the growing of field peas without irrigation has not proved profitable, mainly because of injury to the crop by red spiders. This pest does not seem to do so much damage when the peas are irrigated. Kaiser, a variety which has proved to be one of the most productive to grow on irrigated land, has yielded from 25 to 35 bushels of seed per acre at Burns during the past three years.

TABLE XII. ANNUAL AND AVERAGE ACRE YIELDS IN BUSHELS OF FIELD PEAS GROWN AFTER GRAIN AT MORO, OREGON, FOR THE YEARS 1915 TO 1923, INCLUSIVE.

| Variety | 1915 | 1916 | 1917 | 1918 | 1919 | 1920 | 1921 | 1922 | 1923 | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|
| O'Rourke | 24.5 | 26.6 | 11.5 | 7.1 | 13.3 | 9.5 | 11.6 | 8.3 | 18.3 | 14.5 |
| White Canada | 23.0 | 27.3 | 9.3 | 8.3 | 12.6 | 7.3 | 9.3 | 8.7 | 16.5 | 13.6 |
| Lima | 20.8 | 26.7 | 11.0 | 9.7 | 9.0 | 7.8 | 9.3 | 8.8 | 19.0 | 13.6 |
| Amaroti | 23.3 | 26.0 | 9.4 | 7.6 | 13.3 | 7.3 | 9.3 | 8.0 | 15.1 | 13.3 |
| Cavalier | 24.2 | 26.1 | 8.1 | 3.9 | 12.6 | 6.7 | 12.0 | 7.0 | 15.7 | 12.9 |
| Solo | 20.7 | 30.8 | 8.8 | 9.7 | 7.8 | 4.0 | 8.6 | 8.8 | 16.1 | 12.8 |
| Carleton | 18.2 | 34.8 | 7.2 | 9.2 | 6.7 | 5.1 | 10.2 | 8.8 | 14.9 | 12.8 |
| Bangalia | 21.1 | 18.3 | 9.6 | 4.2 | 14.6 | 7.8 | 12.6 | 7.3 | 14.4 | 12.2 |
| Gregory | 18.2 | 28.9 | 7.7 | 7.8 | 6.5 | 5.1 | 6.2 | 6.5 | 17.1 | 11.6 |
| Kaiser | 18.7 | 28.9 | 8.2 | 7.2 | 6.0 | 6.3 | 3.6 | 8.5 | 15.7 | 11.5 |
| Admiral | ------ | ------ | ------ | ------ | ------ | 13.0 | 8.7 | 9.3 | 19.0 | *12.5 |

*Four-year average yield.

## CORN

Early-maturing varieties of dent and flint corn can be grown in many sections of Eastern Oregon. The crop, however, has not proved very popular with farmers except in warm districts where it is grown under irrigation. Corn is one of the best crops to grow for silage, and its use for pasture and for "hogging down" might advantageously be extended by farmers who keep cows and hogs.

**More corn needed.** There is a place for the commercial production of corn in some of the warm, irrigated sections of Malheur, Umatilla, and Morrow counties and a market in the Northwest for the corn. Enough grain should be grown to replace the present large shipments of corn into the Northwest. Inspection records show that for the year ending September 30, 1922, sixteen hundred and fifty-two car-loads of corn were inspected in Oregon and Washington, and for the next year eighteen hundred and twelve cars were inspected. Many cars went to non-inspection points so that not less than 2000 cars of corn, worth approximately $1,500,000.00, are now annually being shipped to these two states. Practically all of this corn was shipped from states east of the Rocky Mountains.

Trials at Moro with several corn varieties for a period of years have shown that yields of from fifteen to twenty bushels per acre can generally be obtained from early-maturing varieties. Northwestern dent, Minnesota 13, and Walla Walla White dent, have been the three best varieties tried, each of these varieties when sown after wheat averaging about twenty bushels per acre of grain. Because of higher prices and superior quality for dry lot feeding, standardization on yellow varieties is recommended.

Due to early and late frosts during the growing season the branch experiment station at Union has thus far not been able to mature any variety of field corn with any degree of certainty. There are several varieties, however, that will mature sufficiently for silage purposes. Possibly the most dependable of these is Minnesota 13, a very good corn for this section of Eastern Oregon. Under favorable conditions it will yield from eight to ten tons of green fodder per acre.

Corn cannot successfully be grown at the Burns Branch Station because of the prevalence of late spring and early fall frosts.

Winter wheat yields after corn in the rotation experiments at Moro have averaged about nine bushels per acre less than winter wheat after fallow. Disking and harrowing are the only tillage operations required to prepare a seed bed for cereals after corn. The cost of growing grain after corn, like growing grain after peas, is considerably less than growing grain after fallow, because of the expense of plowing and of cultivating the fallow. The successful growing of cultivated crops like corn and peas on the dry lands of Eastern Oregon depends not only on getting high enough yields of corn or peas to pay production costs, but also on securing enough profit from growing these crops to compensate, in part at least, for the usual reductions in grain yields following corn and peas as compared with growing grain after fallow.

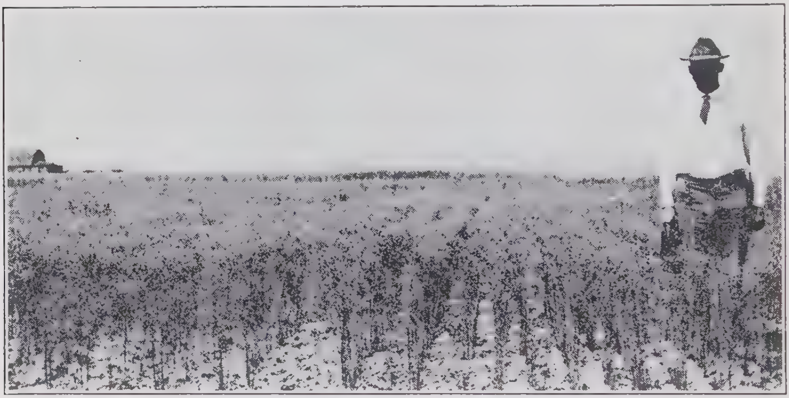

Fig. 14. Flax grown on dry land at the Harney Valley Branch Station, Burns.

## FLAX

Recent reports from the United States Department of Agriculture state that the 1923 flaxseed crop for the United States was about 17,400,000 bushels, which, according to official estimates, is less than 50 percent of our actual requirements for the year. With an import duty of 40 cents per bushel and a shortage in production of at least 20,000,000 bushels and a present market price at Portland around $2.40 per bushel flax grown for seed might be a profitable spring crop for Eastern Oregon farmers to consider.

During the past five-year period from 1918 to 1922, inclusive, the average market price for flaxseed in Portland has been $3.15 per bushel of 56 pounds. Our local Portland Mills have a present capacity sufficient to handle in the neighborhood of a half million bushels of flax per year.

The branch experiment station at Union began growing flax as early as 1910. It has demonstrated that both fiber and seed varieties can be grown successfully in certain sections of Eastern Oregon where conditions are favorable for this crop.

The average acre yield of seed flax in the United States is 8.5 bushels. When grown under field conditions at the Union Branch Experiment Station yields ranging from eleven to seventeen bushels per acre were obtained.

Limited trials with flax have been made at the Moro Branch Station, but the crop thus far has not proved successful.

At the Burns Branch Station flax has done well on irrigated land but has not shown much promise as a dry-land crop.

## POTATOES

Limited experiments have been conducted on the branch stations in Eastern Oregon to determine the potato varieties best adapted for this area. Under the dry conditions prevailing at Moro, potatoes have been tried both after grain and after fallow. When grown after fallow, fair yields have been obtained from a number of varieties. The leading ones are listed in Table XIII.

There are a number of districts in Eastern Oregon where the growing of potatoes by farmers for the commercial market and for seed is being successfully carried on both with and without irrigation. It has been found under dry farming conditions such as prevail at Moro that the one most important item influencing yields is the planting of disease-free seed. In the experiments at Moro, nearly all potato varieties have proved almost valueless for seed after being grown there for two years. In fact, the yields are greatly reduced when seed is used that has been grown more than one year. The introduction of disease-free seed at frequent intervals appears necessary for successful potato growing on the drier lands of Eastern Oregon.

The production of potatoes on a commercial scale in Eastern Oregon should be limited to sections especially suited to this crop. Yields obtained at Moro as shown in Table XIII indicate that satisfactory yields might be obtained from potatoes for home use by the average farmer. The crop should always be grown on land which was summer-fallowed the previous year. Much better yields of potatoes have been obtained after fallow than when planted after grain.

TABLE XIII. ANNUAL AND AVERAGE YIELDS OF THE LEADING POTATO VARIETIES GROWN AFTER FALLOW AT MORO, OREGON, FOR THE YEARS 1916 TO 1923, INCLUSIVE

| Variety | 1916 | 1917 | 1918 | 1919 | 1920 | 1921 | 1922 | 1923 | Avge. |
|---|---|---|---|---|---|---|---|---|---|
| Idaho Rural | 296.0 | 80.0 | 145.0 | 125.0 | 170.0 | 150.5 | 207.0 | 211.0 | 173.0 |
| Early Rose | 251.0 | 116.0 | 148.0 | 140.0 | 168.0 | 151.0 | 146.0 | 230.0 | 168.7 |
| Irish Cobbler | 219.0 | 135.0 | 126.5 | 105.0 | 119.0 | 161.0 | 142.0 | 150.0 | 144.7 |
| Early Ohio | 171.0 | 126.0 | 155.8 | 67.5 | 154.0 | 143.0 | 157.0 | 138.0 | 139.0 |
| Netted Gem | 214.0 | 47.0 | 85.0 | 135.0 | 127.4 | 137.0 | 100.0 | 192.0 | 129.7 |

Of the varieties listed in Table XIII, Idaho Rural has given highest yields. This is a medium-early maturing variety which is quite widely grown under irrigation in southern Idaho. It appears to be a little less injured by disease at Moro than many of the other varieties. The quality of the Idaho Rural variety is fair and good yields have been obtained from this variety when new seed is used at least every third year.

The second highest yielding variety was Early Rose. The quality of this well-known variety when grown on dry lands was only fair, and during some seasons it made considerable second growth.

For quality, the Irish Cobbler and Early Ohio on the average have been the best varieties grown at Moro. These two varieties mature early and rarely make second growth. The yield of the Early Ohio variety in 1919 was considerably lower than that of the other varieties because of the fact that the seed planted had been grown at Moro for two years previous and the high percentage of disease in the crop cut down the yields.

The yields of most of the other varieties listed in Table XIII are from seed obtained each year from other localities, or from seed grown at Moro only one year. In a few instances it was necessary to use seed grown at Moro for two years, and reduced yields invariably resulted when such seed was used.

At the Burns Branch Station, under irrigation, Early Ohio averaged 217.4 bushels per acre for the three-year period 1921 to 1923, inclusive, and Netted Gem averaged 185.9 for the same period.

At the Union Branch Station all potato varieties tested have given very satisfactory yields.

For further information regarding potato growing and the control of potato disease, consult Oregon Station Circulars 24 and 25.

## SUMMARY

The cereals—wheat, barley, rye, oats, and corn—constitute the chief source of farm income in Eastern Oregon. Of these, wheat and rye are usually grown from fall sowing.

Fall-sown cereals are generally more productive than when spring-sown, especially if preceded by summer fallow.

Large areas in Eastern Oregon are devoted to spring-sown grains, especially wheat and barley. The average acreage sown to spring wheat for the past five years exceeded that of winter wheat in twelve counties in Oregon east of the Cascades. Jefferson county's acreage was highest, averaging 31,130 acres, and Union county was second with an average acreage of 28,025.

Experiments to determine the best varieties of spring-sown crops to grow have been in progress on the three branch stations in Eastern Oregon since their establishment. One of these stations is located at Moro where the average annual precipitation is 11.52 inches, one at Union in Union county, where the average annual precipitation is 14.03 inches, and another at Burns in Harney county, where the average annual precipitation is 8.18 inches.

At the Moro Branch Station, the Federation, Hard Federation, and White Federation spring wheats have proved superior to all other spring-sown varieties. At Burns, the Federation variety exceeded all other varieties when grown under irrigation, and Baart has slightly exceeded the average yield of Federation wheat, when grown on dry land.

Preliminary trials at the Union Branch Station indicate that the Federation variety will prove a valuable spring wheat for that section of Eastern Oregon. Trials by farmers under dry-farming conditions on lighter soil have shown that Hard Federation has exceeded the average yield of other spring wheats grown in Union county.

Trials by farmers in Umatilla, Union, Wallowa, Baker, Malheur, Deschutes, and Crook counties, indicate that Federation and Hard Federation spring wheats will likely soon supplant all other spring wheat varieties in Eastern Oregon. The Federation has proved to be an especially high yielding wheat under irrigation. When fall-sown, it exceeded the yield of all varieties in Umatilla county ten bushels per acre in 1923. It is not recommended for general sowing in the fall.

Milling and baking trials conducted by the Section of Milling Investigations, Grain Division, United States Department of Agriculture, show that Hard Federation is a very satisfactory wheat for breadmaking, being better than Baart or Pacific Bluestem and about equal to Marquis. The quality of the Federation variety grown on dry land appears to be about equal to Baart for breadmaking. When grown under irrigation, the Federation variety appears to be somewhat superior to Dicklow as a milling wheat.

Barley is the most productive crop for spring sowing in Eastern Oregon. At the Moro Branch Station, the best varieties were Mariout and Peruvian. At Union, Trebi and Hannchen proved to be the highest yielding varieties. At Burns, under irrigation, highest yields were obtained from Trebi. Hannchen proved best on dry land.

Oats have not proved as productive on dry land in Eastern Oregon as barley. The highest yielding varieties at Moro have been Markton, an early, smut-immune variety, and Three Grain, a midseason, plump-kerneled variety. At Union best results have been obtained from Silvermine, and at Burns, under irrigation, Early Mountain has yielded highest for the two years it has been tried.

Aside from the cereals, field peas have been one of the most promising crops grown on the branch stations in Eastern Oregon. Average yields of from 12 to 14 bushels per acre have been obtained at Moro from this crop when grown after grain in cultivated rows. The highest yielding varieties have been O'Rourke, Lima, and White Canada.

At the Union Branch Station field peas have been successfully grown for the past fifteen years for seed and for hay and silage in grain mixtures. The white Canada variety has averaged about 25 bushels per acre when grown for seed. Peas and barley have produced from eight to ten tons of green feed per acre.

At Burns, in Central Oregon, the most satisfactory field pea variety to grow on irrigated land has been Kaiser. On dry land, field peas have not been successful at Burns because of injury to the crop by red spiders.

In feeding experiments at the Union Branch Station, field peas have proved superior to the small grains for feeding hogs. Field peas have been successfully used for pasture for hogs and sheep at each of the three branch stations in Eastern Oregon.

On the branch station at Moro, Minnesota 13, Northwestern dent, and Walla Walla White dent have been the highest yielding corn varieties. These varieties when grown after grain averaged nearly twenty bushels per acre in yield. For silage, Minnesota 13 has been one of the most satisfactory varieties at Union. The use of corn for silage, for pasture, for hogging down, and for sale as grain, should be increased in Eastern Oregon.

Results with flax at Union indicate that this crop might prove profitable in certain sections of Eastern Oregon. At Moro, flax has not shown much promise. It has done well at Burns on irrigated land but it has not proved profitable on dry land.

Potatoes have given fair yields under dry-farming conditions at Moro when grown after fallow. The highest yielding varieties have been Idaho Rural, Early Rose, and Irish Cobbler. At Burns, under irrigation, Early Ohio outyielded the Netted Gem variety.

It is important to secure disease-free potato seed to get satisfactory results.

Station Bulletin 205 May, 1924

Oregon Agricultural College

Experiment Station

# Drying Prunes in Oregon

By

ERNEST H. WIEGAND

1885

CORVALLIS, OREGON

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# Drying Prunes in Oregon*

By

ERNEST H. WIEGAND

The growing conditions of Oregon are peculiarly adapted to many varieties of prunes. The French prune, commonly known as the petite, and the date prunes are chief among the sweeter varieties commercially grown. The more tart prune, the Italian prune, however, is the most common of Oregon prunes.

The first Italian prune stock entered Oregon about 1857. It is known as the Fallenberg prune and came originally from Europe. There is a large acreage of this variety of prune in the Pacific Northwest.

At the present time more care should be given to the orchards already planted. Any increase in acreage could well be sacrificed for this end. It is far better to have a shortage of high grade prunes than an excess of poor quality stock.

Orchard investment is permanent. Large sums of money are involved in the growing of an orchard; in cost, upkeep, and depreciation of orchard equipment; and in construction of a dryer and operating machinery.

## EVOLUTION OF THE EVAPORATOR

One of the most interesting and involved phases of the prune history is that of types of evaporators. Years ago it was realized that a more uniform product was needed, and the only way to obtain such was in the proper construction of the drier. As Hedrick† put it: "The importance of the erection of evaporating plants, and more efficient management of them can hardly be estimated. A good evaporator is the prime essential to success—if for no other reason than that there is at present such a wide range in quality and style of product that it has no established place on the markets."

Even as recently as a year or two ago, it was recommended to an inquirer who desired to build an evaporator that he visit and inspect the various driers in the state or elsewhere, and from them conclude the best type to build. Such was the best that could be done since the experimental work on the real factors that should dictate the construction of the drier had just begun.

Few other fields have offered as great an opportunity for mechanical ingenuity as the field of dehydration. Literally hundreds of types of driers have been built with every possible turn of construction to accomplish the desired end. Starting from the hop kiln in its almost startling simplicity, there existed as early as 1897 such complicated structures as the Penniman evaporator.

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*With a view to determining the effect of various pretreatments, drying temperatures, and humidities on the rate of drying and the quality of dried Italian prunes, a series of experiments was carried out at this Station in collaboration with Ray Powers of the Bureau of Chemistry, United States Department of Agriculture. These experiments covered a wide range of temperatures and humidities and were under carefully controlled conditions. The data presented and the conclusions drawn in this bulletin are the result of this work.

†Prunes in Oregon. Oregon Agricultural Experiment Station Bulletin 45.

## PRINCIPLE SIMPLIFIED

The fundamental principle sought at that time for the most successful drying is present today in a much simpler and more efficient mechanical form, that of moving the air over the fruit instead of moving the fruit through the air. Because of its cheapness and simplicity, and the need for a small capacity evaporator, the natural-draft drier took precedence over the mechanical draft, following an order of evolution from the hop kiln to the box evaporator which contained the fruit on trays instead of the floor. Then came a modification by changing the source of heat to steam pipes just under each tier of trays.

In the Carson evaporator the floor opened the full length, and permitted the hot air from the furnace chamber to pass through the trays placed on sloping tray racks. This approaches in a way the horizontal type, as did the Allen evaporator which through various modifications has come down to the present time as the Oregon tunnel.

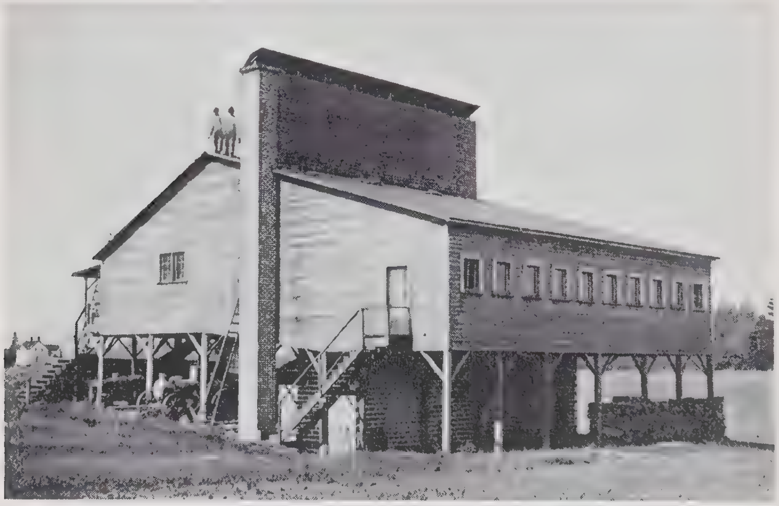


Fig. 1. Oregon tunnel drier, C. R. Widmer, Albany.

The superior method of drying by mechanical draft has been the only method possible to use in Oregon, but for various reasons has not received, until recently, the proper scientific attention to harness its great potential powers for accomplishing the production of a superior product. In fact, with the admission of the failure to establish a sound and uniform basis of drying has come the desire, with moral and financial backing, for proper scientific work.

These brief opening remarks are intended to show that there is nothing new in the principle of dehydration; but that there must be an awakening to recognized needs.

Care for the orchard properly, work for a high-quality product in so far as best effort will allow, and be keenly alert to all improvements that are advanced. This will insure in the near future an excellent standardized product.

## STANDARDIZATION

There is nothing better than the best, and the best is in demand. Italian prunes will be a source of prosperity to the people of the state just to the extent of the market demand, which is primarily dependent on quality. A standard product is a guaranteed-quality product. Brokers, commission men, wholesalers, retailers, and consumers all call for a product which retains its identity from year to year. Once this is achieved there can be no separation of the prune from its quality and the market demand will continue.

For natural quality the dried Oregon prune has a decided advantage. It has the basic elements of a mild, aromatic tartness and a high percent of sugar from which to produce artificially and maintain an excellent product in popular demand.

The importance of standardization and economical production must be recognized in all the steps in the production of a dried prune. For the purpose of the present discussion, we will recognize five steps:

1. Sanitation in handling.
2. Growing and harvesting the fruit.
3. Preparing the fruit.
    (a) Grading.
    (b) Dipping.
    (c) Traying.
4. Drying.
5. Processing and packing.

## SANITATION

Sanitation is part of standardization. Several generations have passed since commercial canning and drying began, and still there remains a passing hesitancy on the part of the consumer to eat dried products. No doubt there was ample reason in the early days for this hesitancy or refusal to use the commercially prepared foods. With our modern methods, there should be reason now for using the dried and canned products as greater care is taken in all the steps of food production.

The artificially dried prune has every chance possible to be, if you might so term it, "ultra-sanitary." This would require only ordinary care from the time the prune is picked to its final placing in cartons or boxes for shipment.

Sanitation should start in the field. All boxes used should be clean, and the pickers should be constantly warned against putting rotten or moldy fruit with the good. This will insure the prune in the best condition for delivery to the drier.

It is often required, and very rightly so, that all fruits or vegetables in transit to the drier be covered to prevent the road dust from settling on the exposed surface. Even with these precautions, however, the prune should be washed before it is placed in the drier. This step is very important. If lye solution dipping is not used, boiling or hot water should be used, and in either case there should be a rinsing in cold water. Especially should this be very thorough with the lye-dipped product.

Holding the prunes in the lug boxes should be avoided. It is a difficult but important part of drier management to have the fresh fruit out of the lug boxes and into the drier within twelve to twenty-four hours. Lack of tunnel capacity to care for the crop is a very great handicap in drying a high-quality sanitary prune.

All precaution thus far taken would be of little worth if the dried product were permitted to come in contact with dirt and dust before being packed. All storage bins should be covered, and care should be taken in handling the fruit. Only helpers who are clean in their habits and careful in their work should be employed.

## GROWING AND HARVESTING

Methods of orchard practice such as selecting a site, cultivating, pruning, and harvesting are not within the scope of this bulletin, but a brief word will at least properly emphasize the importance of good condition of the fresh fruit to insure a superb dried product.

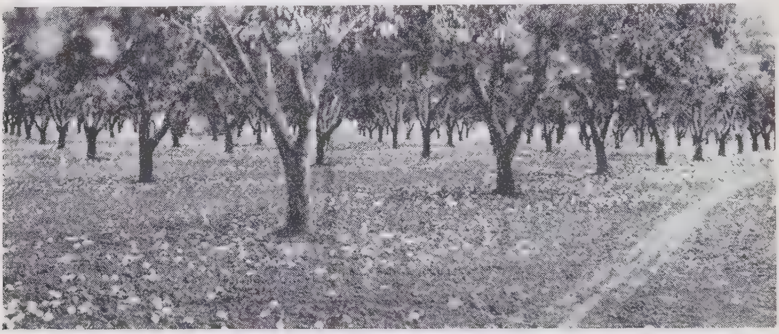


Fig. 2. Italian prunes ready for first picking.

A high-quality prune must have plenty of moisture and be as near ripe as possible at picking time. Some authorities claim that the red prune is due to lack of plant food, others that it is because of too little moisture, or that it may be due to the stage of maturity.

It is of utmost importance that the prune be brought to the drier as a first-class, ripe, fresh fruit if it is desired to obtain a high-quality dried product.

Lug boxes are very much in evidence around the drier during the harvesting of the prune. Much can be said for and against the use of the large lug or field box in handling prunes from the orchard to the drier. This box, holding on the average sixty pounds of fresh fruit, is unwieldly and unsanitary, causing the fruit to mash, besides promoting the development of brown-rot *(Sclerotinia ceneria)* in case the fungus is present. The use of the small lug box commonly used in California would in a greater measure reduce the loss, especially in wet years when the brown-rot is more prevalent and the fruit becomes soft before harvesting. Less bleeding and over-heating would occur at the drier if the fruit were allowed to remain in this type of orchard box.

The quality of the prune cannot be raised above the condition of the fruit as it is trayed for drying. If the fruit is mashed, sour, or moldy, it will dry as such, or if it is in a soft condition, trayed and left standing (for want of tunnel capacity), it will mold much more quickly than the firm fruit.

## PREPARING THE FRUIT

**Grading.** Grading before drying has been practiced to some extent in the past. Although there is merit in the procedure, certain points of disadvantage have not permitted definite conclusions. The difficulty lies in the kind of machine used as most types tend to mash or skin the fruit, doing as much damage as good. There are two types on the market; the protected roller type which gradually widens, dropping the fruit according to size, and the shaker type with holes, grading from smaller to larger. As it is recommended that the fruit be picked at the ripe stage, grading would hardly be feasible in such cases because of mashed and bruised fruit.

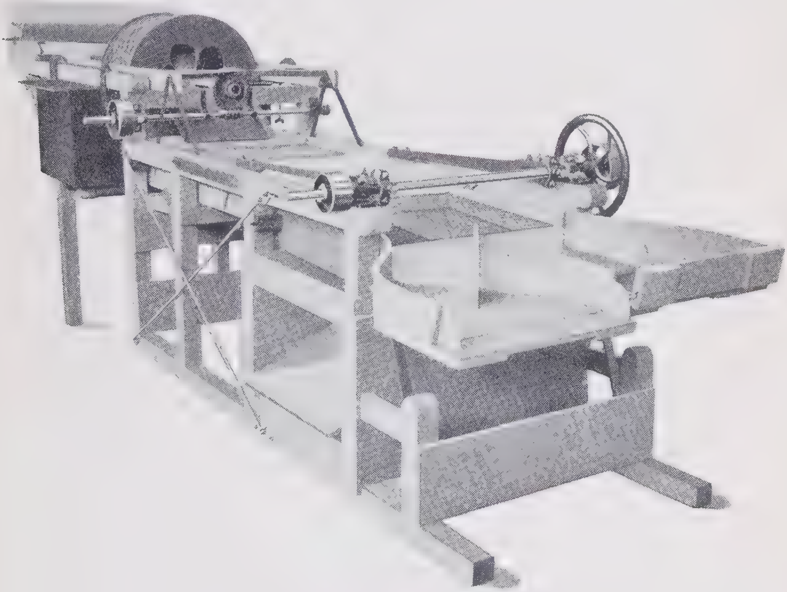
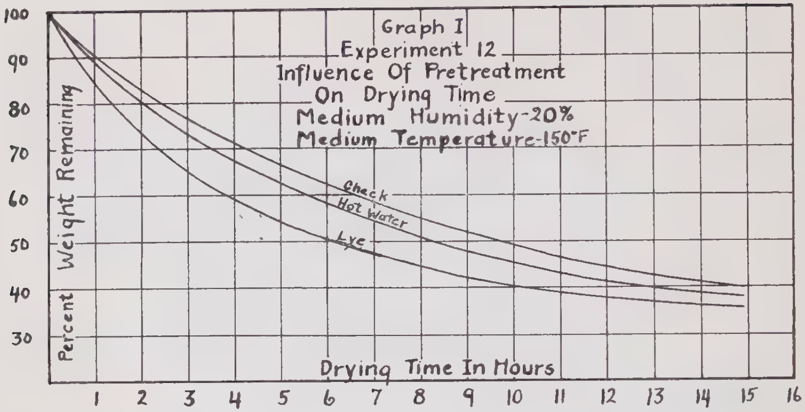


Fig. 3. Shaker type grader and perforator. (Courtesy Anderson Barngrover Mfg. Co.)

Much of the difficulty in uneven drying is due no doubt to the mixed sizes of the fresh fruit. This difficulty may be reduced by increasing the circulation with lower temperatures and higher humidity. This has been indicated by the first season's work on the proper relation of the factors, temperature, humidity, and circulation.

It might be further added that in the natural-draft tunnel, there is invariably a lack of uniform drying on the trays because of air pockets and channeling which would make useless a sizing of the fruit before traying.

**Dipping.** The Italian prune, covered with a rather impervious, waxy skin, has been pretreated at various times and in various ways for the


Graph I
Experiment 12
Influence Of Pretreatment
On Drying Time
Medium Humidity-20%
Medium Temperature-150°F
Check
Hot Water
Lye
Percent Weight Remaining
Drying Time In Hours
100
90
80
70
60
50
40
30
1
2
3
4
5
6
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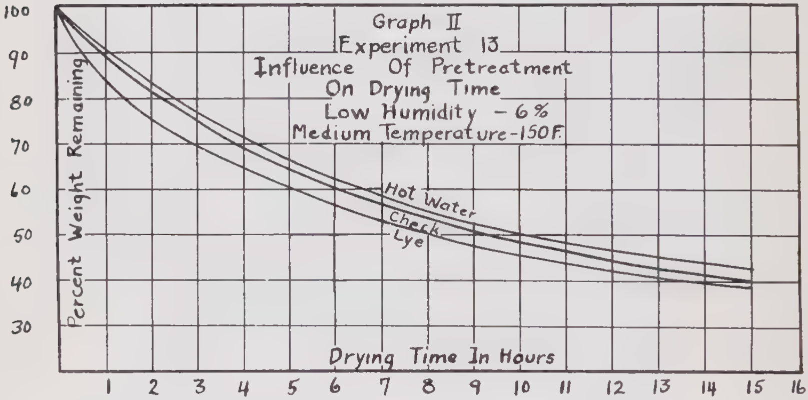
Graph II
Experiment 13
Influence Of Pretreatment
On Drying Time
Low Humidity - 6%
Medium Temperature-150F.
Hot Water
Check
Lye
Percent Weight Remaining
Drying Time In Hours
100
90
80
70
60
50
40
30
1
2
3
4
5
6
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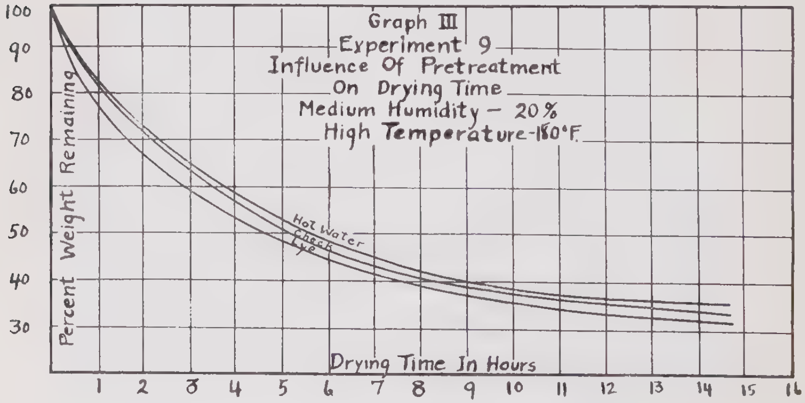
Graph III
Experiment 9
Influence Of Pretreatment
On Drying Time
Medium Humidity - 20%
High Temperature-180°F.
Hot Water
Check
Lye
Percent Weight Remaining
Drying Time In Hours
100
90
80
70
60
50
40
30
1
2
3
4
5
6
7
8
9
10
11
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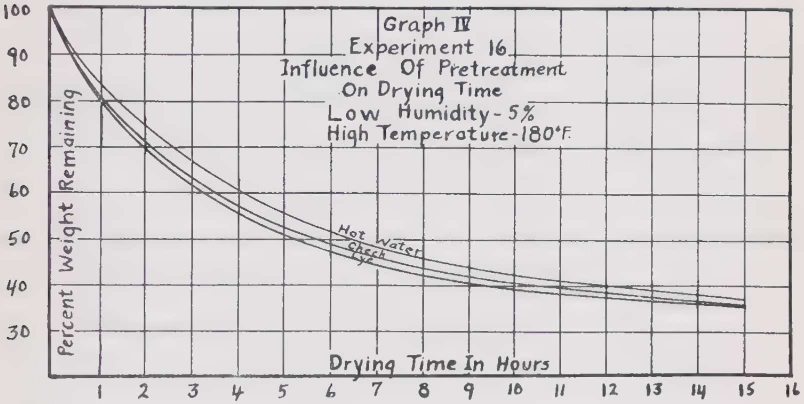
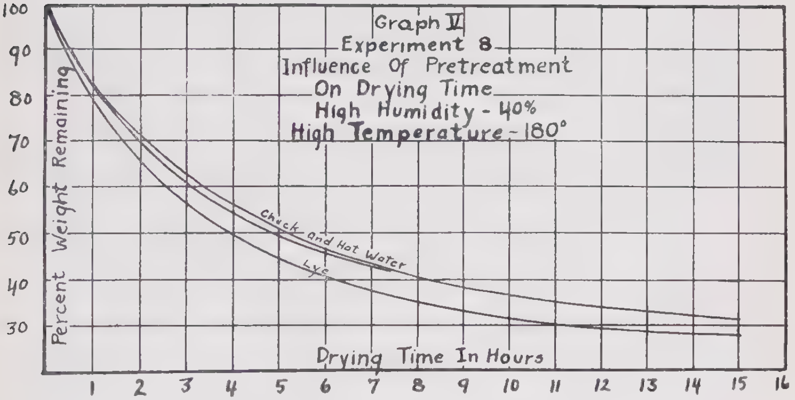
purpose of checking or cracking the surfaces. There are three methods in general practice: lye dipping, hot-water dipping and ordinary washing. Graphs I, II, III, IV, and V show the results on drying time of fruit treated the above ways and dried under several combinations of temperature and humidity.

At a temperature of 150° F. graphs I and II show an advantage in lye dipping. When a medium humidity is used the drying time is shortened by two to three hours over that required to dry prunes subjected to very little humidity.





With a high temperature and a low medium humidity (graphs III and IV), the check or untreated fruit dried as quickly as the lye. The hot-water dipping probably had no effect on the drying at the temperature stated. With the humidity high and the temperature high (graph V), the lye-treated fruit dried more quickly than either the hot-water dipped or the check.

Certain explanations may be given for these results. It may be that there is not the tendency toward moisture retention with the mechanical draft because under any and all conditions of temperature and humidity there is a limit to the diffusion rate. This would permit the untreated fruit to dry as quickly as the treated.

Until further work is done no definite conclusion can be made. There is little doubt, though, that in most cases the untreated fruit makes the best appearance, and packs with the least cracking or splitting after processing. This has been found true in commercial practice and is probably due to the method of dipping rather than the lye itself. When using lye, it is advisable to use solutions which are not too strong (not over 1½ percent), but keep them boiling hot. Prunes should not be kept any great length of time in this solution.

**Traying.** Many attempts have been made to find a metal tray that would not corrode or react with fruit and vegetable acids, and that would withstand the action of sulfur fumes. So far, even the most expensive alloys have not given entirely satisfactory results. The galvanized iron tray is in very general use in Oregon, and if it is kept clean and not used for sulfuring, it will dry a prune free from marks and with very little, if any, reaction from the metal.

In California the slat wooden tray is used and advocated. There is no reaction of the fruit with the wood but the circulation is not as good nor will the trays stand as rough handling.

For highest quality, it is essential that the trays be cleaned whenever the product sticks to the slats or wire.

Great care should be taken in the handling of the fruit on the trays. As the prunes come from the dipper, they should be placed on the trays in an uncrowded condition with the least amount of shaking. If the trays are stacked, sufficient space should be allowed between them to permit good ventilation. In placing and removing the tray, carelessness often results in scraping and mashing the fruit on the tray beneath. This not only damages the fruit so bruised, but causes excessive dripping, which spoils the appearance of the fruit placed below in the drier.

## DRYING

Evaporators are of two general types; namely, (1) natural draft and (2) mechanical draft.

Of these two types there are numerous designs. During forty years or more there have been many ingenious devices placed on the market to aid drying. Actuating such a variety of constructions there have been the incentives of increasing capacity, of shortening the drying time, and of improving the quality. Too often the motive has been exploitation by certain individuals whose one and only objective was to make money in the commercialization of an idea without any effort toward sound principles of fruit evaporation and positive adaptability. The drierman contemplating building or remodeling his drier should investigate the advertised evaporator or dehydrator and make sure of its value before investing, or he will take chances not only with his money, but also with his good disposition in trying to dry his crop successfully. This does not mean that all patented dehydrators are not good, but rather that care should be taken in selecting one.

A discussion of the types of driers will not be taken up in this bulletin. Suffice it to say that whatever type is used, it should permit control of temperature, circulation, and humidity. It would be impossible even with control knowledge at hand to make use of it in the natural draft tunnel. The reason for this is obvious when it is realized that the temperature a fruit can stand is dependent to some extent on the circulation, and that the capacity of a tunnel per cubic foot is dependent, in some respects, upon the volume of air per minute, which will vary with circulation. In other words, nothing definite can be stated unless all factors, including circulation and humidity, are under the control of the operator. This is impossible with the natural-draft tunnel. So far, observation taken under actual working conditions throughout a season's drying in seven or eight natural-draft tunnels has given no other conclusion than that it is impossible to control circulation and humidity and therefore the proper relation of the factors in drying. This would seem to indicate possibly, that there is nothing to do, nothing to watch or improve, in order to put out the best quality prune in the natural-draft tunnel. Such is not the case, however, for if proper attention is given the drier and the items of construction are followed, better circulation and better air distribution will result.

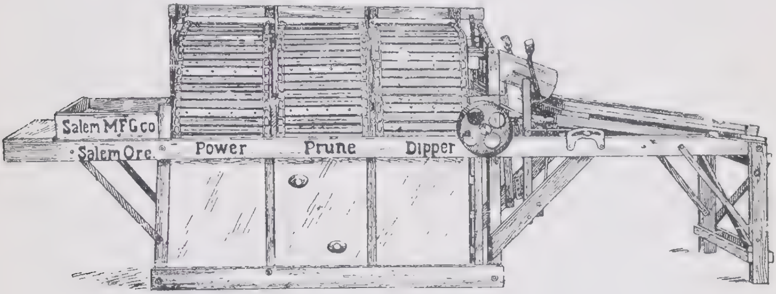


Fig. 4. Continuous Dipper and Trayer.
(Courtesy Salem Mfg. Co.)

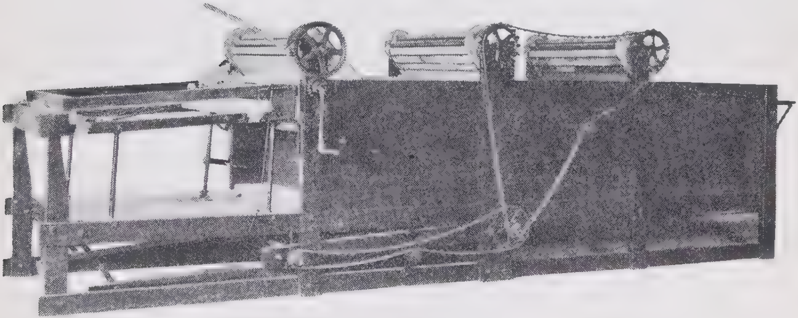


Fig. 5. Continuous Dipper and Trayer.
(Courtesy August Hilfiker.)

Accepting the tunnel drier as the best natural-draft tunnel in use, the construction and operation should follow an investigation of the conditions to be considered. In other words, preceding the selection of the best type of tunnel or drier there should be a study of the factors (temperature, humidity, and circulation) adapted to the principle of drying. In the building of an auditorium or a schoolhouse, the items of ventilation, light, sound, and convenient and economical arrangement are the actual guides. The same principle applies in the construction of a dehydrator.

**Temperature.** Heat is the first essential that comes to the mind when discussing the drying or evaporating of any product. There is no doubt that it is first in the cost column of production, both as an initial investment, and as a running expense.

Heat and quality of product are very closely associated. Quality may be lowered by heat in the following ways:

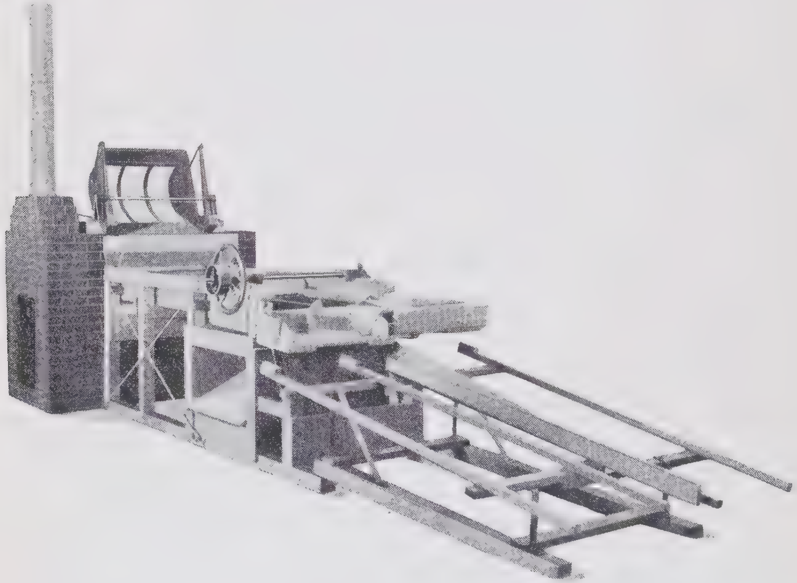


Fig. 6. Controlled Dipper, Grader and Trayer. (Courtesy Anderson Barngrover Mfg. Co.)

1. Too high initial temperature, which causes dripping.
2. Too high finishing temperature, which causes bloats, burns, and caramelization.
3. Too low temperature and a resulting long drying time in the tunnel, which may cause fermentation and often a moldy condition.

**Humidity.** Moisture is commonly considered as an enemy of drying. Moisture in the circulation lessens evaporation, but in the long run moisture in certain amounts will increase evaporation by permitting a steady, uniform conduction and diffusion. Under these conditions a better quality prune will be produced.

Moisture influences quality and economic production by (1) preventing case hardening, and (2) increasing the conductivity of the air.

**Circulation.** Air is the medium in which the heat and moisture act. The moving air is the conveyor of heat, and the conductivity of the heat is increased when moisture is present.

The velocity of circulation influences quality and economic production by controlling to some extent the rate at which evaporation takes place under any given set of conditions.

1. It may lessen chances of scorching (cooling effect).
2. It may decrease the drying time.

The interrelation of circulation, moisture, and temperature in their best combination, while not positively known, may be given in so far as experiment and practice have shown.

Evaporation is a common, every-day physical fact. It is recognized by everybody and is given no other thought than the accepted idea of a liquid disappearing into space. We almost instinctively associate wind, dampness or moisture in the air with drying. On a windy day, things dry very rapidly; while on a hot, sultry, or damp day, there is a retarding of the process, and we say it is close and uncomfortable. In certain sections of the country, a very high degree of temperature can be tolerated with little suffering, while a much lower degree of temperature in other places causes prostration and death. Damp heat and damp cold are very noticeable, not because of more heat or cold, but because the water vapor in the air makes the air medium a better conductor.

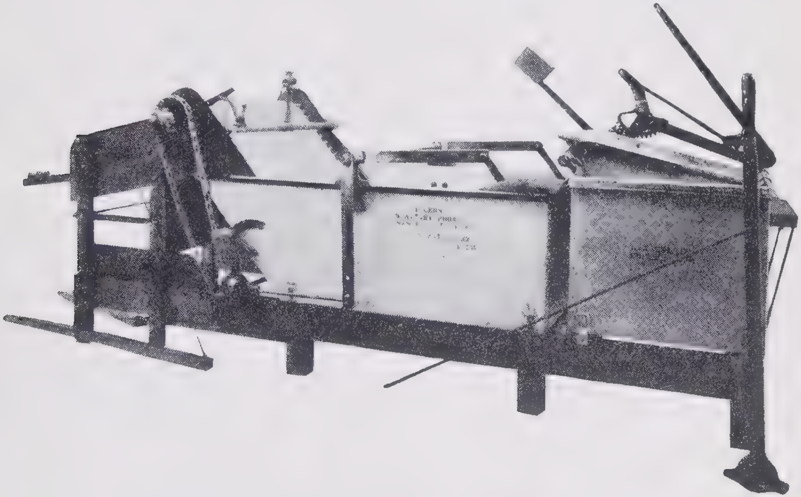


Fig. 7. Controlled Dipper and Trayer.
(Courtesy L. N. Miller.)

If we put these common, every-day hints together, we can say that:

Increasing temperature increases evaporation.

Increasing humidity, applied under certain conditions, decreases evaporation.

Increasing circlation increases evaporation.

These facts are like almost all others, in that they have bounds and limiting factors and are subject to the law of application, namely: 1. Evaporation is subject to and dependent upon the medium from which it takes place, such as water, soil, fruit, lumber, etc. 2. The ratio or volume of the product to be dried to the drying power of the factors must be known. 3. There is a limit to the economical diffusion rate of each fruit or vegetable. Whether there shall be constant or changing conditions such as a higher or lower temperature at the beginning or end, and to what extent, if any, humidity accelerates evaporation from fruits instead of decreasing it, depend upon the product being evaporated.

The first and second limitations set are simply those of an overload of fruit to space and physical limit of speed of evaporation.

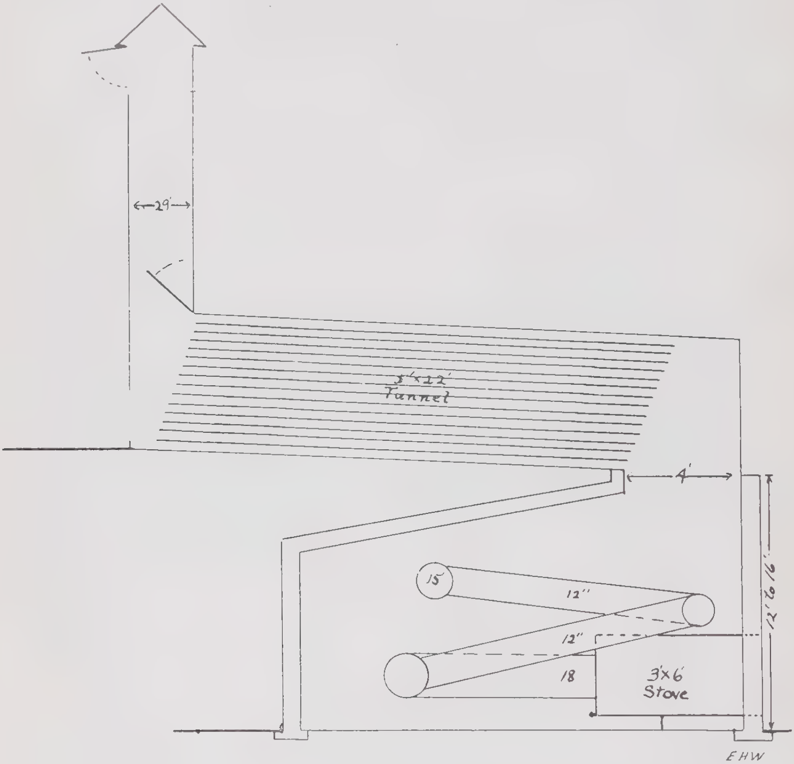
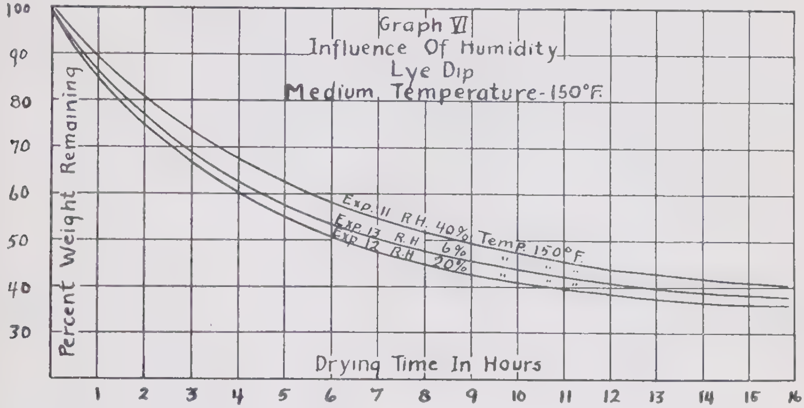


Fig. 8. Oregon tunnel drier.

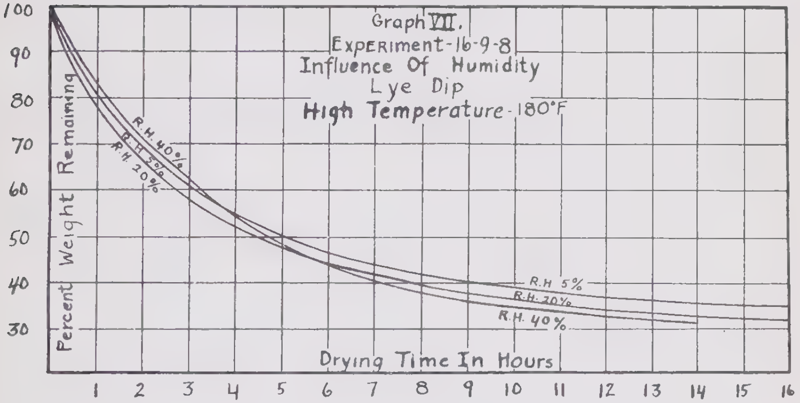
To illustrate: Temperature, humidity, and circulation are working in combination in removing the moisture from the fruit, but depending upon the fruit being evaporated, their power is limited even though their capacity is relatively unlimited. It is desirable that the evaporation be completed in the shortest time consistent with the best quality. Toward this end the following work has been done with as yet incomplete results.

It is seen that the problem of combining three variants is quite complicated. The range of temperature is from 100° F. to 200° F., circulation from 200 lineal feet per minute to 1200 lineal feet per minute, and humidity from the natural to 40 percent.

**Lye dipped.** A very small number of experiments were run since the time and equipment did not permit as thorough a test as should be given. The air movement was not varied and the humidity and temperature were varied to the extent of a medium low and high condition. Nine representative runs were selected upon which to base these results although more runs were made.



Graph VI. Showing the influence of humidity at a medium temperature.*



Graph VII. Showing the influence of humidity at a high temperature.*

Each run was made under controlled conditions. Both humidity and temperature were automatically regulated, and the speed of the fan was kept constant at 1200 lineal feet per minute throughout the run.

Experiments run at a temperature below 140° F. are not practical. Temperature is no doubt the most essential factor in drying. At the beginning of the experimental work moisture was considered important. Results seem to indicate, however, that humidity has to be carefully regulated to local conditions of dryer and fruit. Along with the experi-

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*On the graphs the vertical axis represents percent loss of weight and horizontal axis the time in hours.

Putting these results together and with other work that has been done, an approximation can be made of the best combination of factors, after we know the product to be dehydrated.

The questions to be answered for the specific product are: What temperature, humidity, and circulation shall be used?

In the case of prunes an entrance temperature of 120° to 130° F., gradually increasing to a finishing temperature not exceeding 150° to 165° F. seems most desirable.

A relative humidity between 15 and 30 percent with circulation from 600 to 750 lineal feet per minute appears to give good economic results.

These factors are suggested from the preceding work but not without a complete consideration of quality, which is given its equal in importance. It is to safeguard quality that, in spite of these good drying times, the higher temperatures with low humidity are not advised.

**Natural-draft Oregon tunnel drier.** In the plans submitted it should be understood that there are points of major importance and that there are minor considerations which can be altered best to suit the building site and personal preference. It is always necessary to have in mind the most economical construction consistent with the desired points. Consequently the specifications should be interpreted with an adaptational point of view and a discriminating mind.

The following should be recognized and unquestionably insisted upon in all plans:

1. Depth of furnace chamber 12′ to 16.′
2. Sufficient and properly distributed air intakes into furnace chamber.
3. Sufficient radiating pipe properly placed in furnace chamber, using 36″ x 6′ furnace and 15″ pipe.
4. Air intake slightly in excess to area between trays. (Throat of tunnel.)
5. Slope of tunnel, 1″ to 3″ to the foot.
6. Distance of runs apart 4″ to 4½″ center to center.
7. Stack about 10′ to 15′ high with a ventilator subject to regulation.
8. Length of tunnel from 22′ to 26.′
9. Equipment for washing.

Three to four tunnels to a furnace chamber are found to be satisfactory. The specifications included herein show three tunnels to each stove, the smallest unit possible of construction within economical limits. When thirty or forty tunnels are included in one building it is necessary to have at least one or two runways for trucking and passing back and forth.

The plans show dimensions and all points of construction, and while the above points are important, they are not indicative of constant controlled drying conditions. They will give and permit of the best means of temperature and circulation control, but the best is far from perfect. When the weather changes, drying conditions will change and the periodic spells that are so annoying to the manager of a drier will still be present to test his patience.

The list of materials and labor are submitted below. Labor will vary as will the material, according to local conditions; consequently, no cost is given, although it has been found that $450 to $600 per tunnel will cover entire cost for constructing drier.

Sufficient floor space should be provided for at both ends of the tunnel—at least fifteen to twenty feet. This will allow for trays, trucking, stacking of fresh fruit, dipping and washing machinery, and the sorting and sacking of dried product.

Large, full-sized blue-prints will be sent to any person desiring to construct a unit of tunnels. The following sketch will give the essential features and parts of the drier.

SAMPLE BILL OF MATERIALS—THREE-TUNNEL DRIER.

A. Furnace chamber:

1: 3′ x 5½′ hop stove with 6½ feet of 18″ pipe to header
1: 18″ header, 8′ 3″ long
1: 12″ header 7′ long
2: 12″ elbows
22 feet 15″ pipe for outlet to stack
61 feet 12″ pipe plus 8 inches for each joining
124 building tile

B. Tunnel:

19 feet 4″ x 4″ material
11: 8″ x 12′
6758: 2″ x 4″ material
1848 running feet 1¼″ x 1¼″
6311 feet ¾″ x 3″ flooring No. 1 grade
8: 2″ x 12″ x 12′
540 shingles laid 4 inches to the weather
85 feet small cord rope
3 single pulleys, 3 double pulleys
6: 3″ single strap hinges
18: 5″ double strap hinges
6 bolt latches
6: 4″ double strap hinges
1: 15″ steel smoke stack, 39′ high
336 trays 31″ x 37⅛″ x 1⅝″ (Allowing ⅓ extra)
Roof of furnace chamber may be reinforced with 12 lb. 1½″ round rods 11′ 2″ long —134 feet in all. By using triangle mesh concrete reinforcement (No 168), this could be easily used in either the 24″ or 48″ width. 134 square feet will be necessary.
32.7 cubic yards of concrete for walls and top mixed 1-2-4. Top to be reinforced as previously stated.
44 sacks cement
13.5 cubic yards of sand
26.5 cubic yards of gravel
3.7 cubic yards of concrete for base 11′ 2″ x 15′ 5″
If the ground is soft, base will have to be larger, 1-3-5.
4 sacks cement
2 cubic yards of sand
3 cubic yards of gravel
Total 48 sacks Portland cement
15.5 cubic yards of sand
29.5 cubic yards of gravel

**Mechanical-draft tunnel.** There is nothing exceptionally complicated or technical about a mechanical-draft tunnel. In the past the expense of construction and equipment was uppermost in the mind, with the result that the use of the dryer has been given only a passing consideration.

Work has been done at this Station with the object of simplicity of construction and economy of operation. Considering the thousands of tunnel driers already built, it was reasonable that an attempt should be made to install the mechanical draft and humidity control in these structures. The results were very satisfactory, as can be readily seen by the figures presented.

**Reconstruction Oregon tunnel drier.** The Oregon tunnel drier constructed at the Oregon Agricultural College Experiment Station has been altered by the addition of a recirculating system to meet the needs of a more constant temperature; to increase the relative humidity and to maintain a more constant circulation. As a result of these factors a more uniform product is obtained.

The air was taken from the drier through the floor at the filling end and forced into the enclosed furnace chamber. It was baffled to circulate between the hot pipes and was forced up through the throat of the drying tunnels at a velocity of approximately 1,000 lineal feet a minute. The fact that only a small amount of air was taken in through an opening 2″ x 10″ and only a small amount allowed to escape through a similar opening in the stack, tended to increase the humidity from 18 to 23 percent, which remained fairly constant throughout the drying period. The increased humidity was beneficial in keeping the fruit pliable and in preventing case hardening.

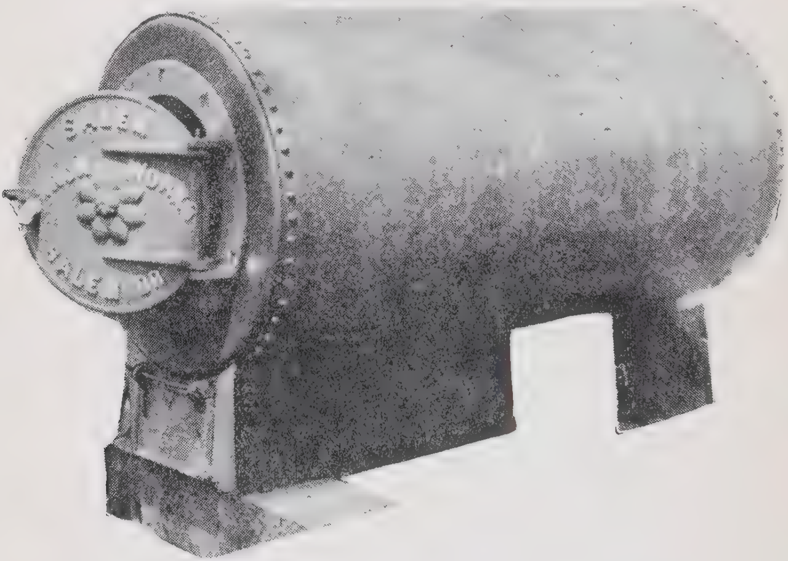

Fig. 9. Type of stove for recirculation or natural-draft drier. (Courtesy Salem Iron Works.)

The consumption of fuel was also reduced to a minimum by recirculation of the air, as only 10° to 20° of heat were lost in passing the heated air through the tunnels. It cost $2.40 for electric power and required one-third of a cord of wood at $6.00 a cord to dry one ton (dry weight) of prunes. The illustration (Fig. 10), indicates the manner in which the air was handled in recirculating. A No. 8 Multivane fan driven by a 7½ horse-power motor was used. A maximum of approximately 750 lineal feet of air a minute was maintained between the trays at all times, and prunes were dried in 18 to 24 hours.

Too much emphasis cannot be placed upon the fan which is to circulate the air. A fan of improper construction and inadequate capacity will cause much grief and will not do the work intended. If it is decided to install a fan for handling the air in recirculation the matter should be referred to the Station before steps are taken to install such equipment. In this way the proper installation can be had at a minimum cost. In the past, fans have been tried and have failed because the operators installed fans of inadequate capacity and of wrong design.

The total cost of equipping the 3- or 4-tunnel Oregon drier with recirculation need not exceed $700, exclusive of power. One fan of sufficient size will be ample to handle recirculation in four tunnels.

Where fans are installed in short tunnels there is a tendency to have a greater dripping. This is due to the fact that the prunes are placed in a tunnel where the temperature is quite high, which causes rapid expansion of the juices and consequent dripping. This can be decreased by increasing the length of the tunnels so that the temperature drop from the throat to the outlet end is greater. Roughly it can be figured that there will be about three-fourths of a degree of heat lost every lineal foot the air travels while passing over the prunes.

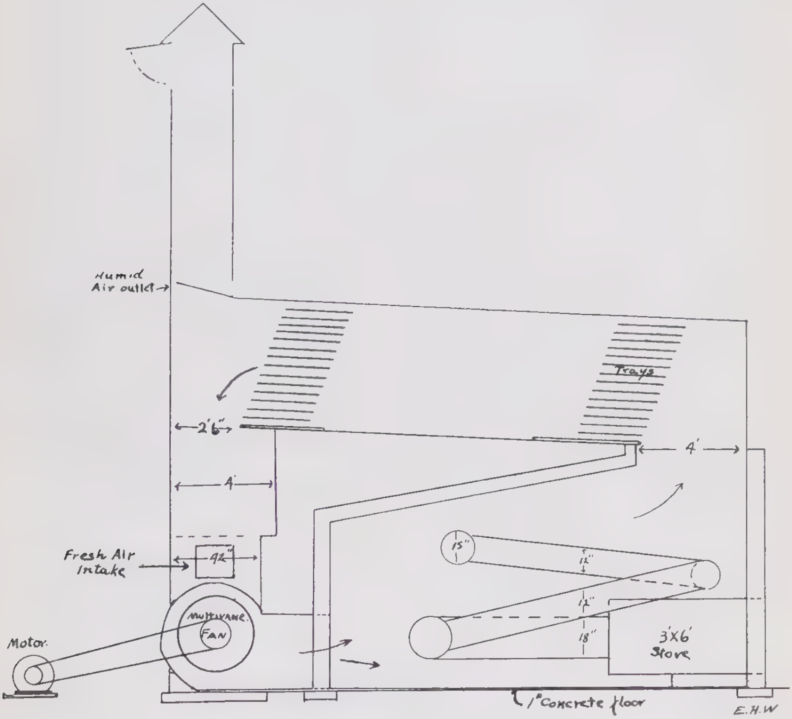

Fig. 10. Reconstructed Oregon tunnel.

## PROCESSING AND PACKING

This last operation before marketing the product is very essential. When it is realized that a medium quality product can often be sold for an extravagant price because of its appearance, there is ample reason for emphasis on the processing and packing of prunes. Appearance is the first and most lasting impression to the public provided the quality is within reason. It indicates cleanliness and care, and stimulates an appetite on the part of the purchasing public.

Various methods are used in processing the prune. In the first place, no prune can be properly processed if it is not properly sorted and sized. You cannot process mashed, rotten, burned, or otherwise poor fruit and expect your good reputation to be maintained. It will appear to improve the poorest but will never make or approximate a good quality product.

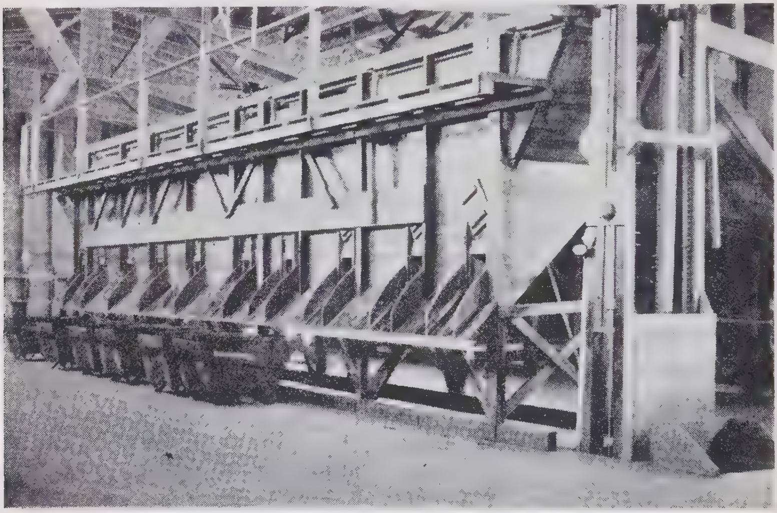

Fig. 11. Dried-prune Grader.

Grading or sizing precedes processing and packing. With prunes this is a very particular point. Sizing is done with screens over which the prunes are shaken—ten or more sizes being recognized. Fig. 11 represents the general type of graders. It is a large, bulky machine situated usually on the second or third floor, from which the prunes are turned into bins and from the bins into the processing machinery and packed. Prunes are packed according to size, the number of prunes in a pound designating the size, such as 20-30's, 30-40's, etc. In making the packed sizes the nine point system is used. This involves the taking of two sizes—say 30's and 40's and mixing them so that the 30's-40's will run close to 39 a pound. Care must be taken to have moisture uniform and constant, otherwise a loss of a percent or two might cause the placing of a pack in the next size with the resulting reduction in market value.

There are various means of processing, but in general there are two methods, involving the use of hot water or steam. The latter seems to be the best method as it is less cumbersome and sterilizes with the least amount of sugar loss. Hot water softens the prunes and causes more

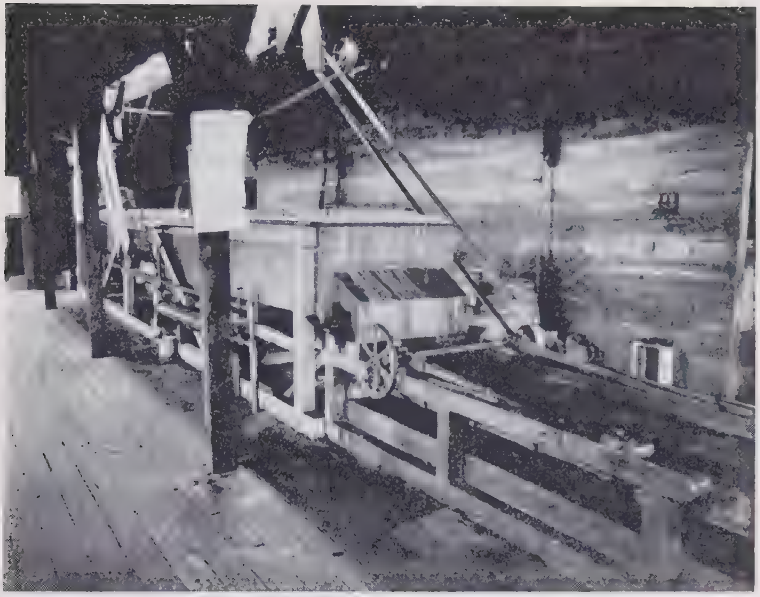

Fig. 12. Shaker type of prune processor.

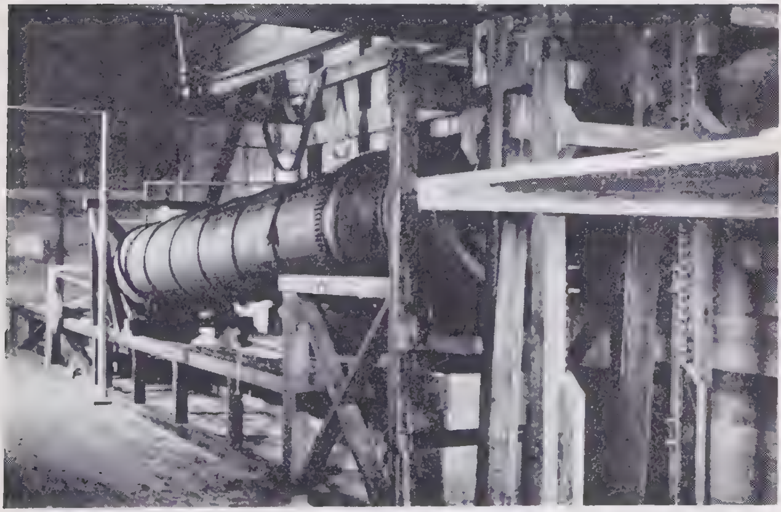

Fig. 13. Drum type of prune processor.

trouble in operating, as it is harder to avoid mushing and gumming the fruit.

Fig. 12 illustrates the general shaker type. Fig. 13 is the drum type, which is not as satisfactory, as it tends to make the fruit sticky and more ragged as the steam condenses, soaking and mushing the fruit.

As the fruit passes through the shaker type of processor (Fig. 12), which is nothing more than a box open at both ends, it receives a spray of warm water at the start, then a minute or so of live steam at a high temperature, finally emerging heated to the pit. Sometimes, at the last, a hot-water spray is given and then a final blast of dry steam.

Packing is done immediately. The fruit being hot dries quickly, and while it is warm and a little damp when put in boxes, it does not necessarily gain or lose much weight. The fruit will gain in weight from nothing to four or five percent, according to the condition it is in, and the method of processing used.

In Fig. 14 can be seen the packing equipment. Ninety percent or more of the prunes are packed in 25-pound boxes. From a hopper above, the prunes are dropped into a paper-lined, 25-pound box, conveyed to the press, and from there to the nailer, ready to be labeled and sold.

## THE MARKET

Prunes may be sold in advance of the crop, but usually only a portion of the crop is sold in this way. This is true both with the grower and the packer. The contracting of fruit is very common; while no figures are at hand, it is possibly safe to say that most of the growers contract for the greater part of their fruit.

The price quoted to the grower by the packer is an agreed price set by the various concerns or a price set by a single concern. It is evident that a large margin is necessary because of the gamble taken by the buyer on the quality and condition of the fruit. Quality in fresh or dried fruit will demand its price or pave a way for its own marketing.

The packer when quoting his price to the brokers and commission men who handle his pack gives a figure below the actual selling price. This is a bulk basis figure and to it is added a regular differential. The following figures represent the system used and the actual opening prices of the Oregon Growers' Cooperative Association for 1921.

MISTLAND CROP

| a. | 30-40 | 40-50 | 50-60 | 60-70 | 70-80 | 80-90 | 90-100 | 100-120 | 120 and over |
|---|---|---|---|---|---|---|---|---|---|
| b. | 8½ | 7½ | 6 | 5½ | 5 | 5 | 5 | 5 | Bulk basis; add regular differential |
| c. | 3¾ | 3¼ | 2¾ | 2¼ | 1¾ | 1¼ | ¾ | ¼ | |
| d. | 12¼ | 10¾ | 8¾ | 7¾ | 6¾ | 6¼ | 5¾ | 5¼ | Price packed in 25-pound boxes less boxing cost |
| e. | 1½ | 1½ | 1½ | 1½ | 1½ | 1½ | 1½ | 1½ | |
| f. | 10¾ | 9¼ | 7¼ | 6¼ | 5¼ | 4¾ | 4¼ | 3¾ | Actual selling price less boxing |

Note that the bulk basis price quoted was 8½, 7½, etc., while the actual selling price per pound was 10¾, 9¼, etc.

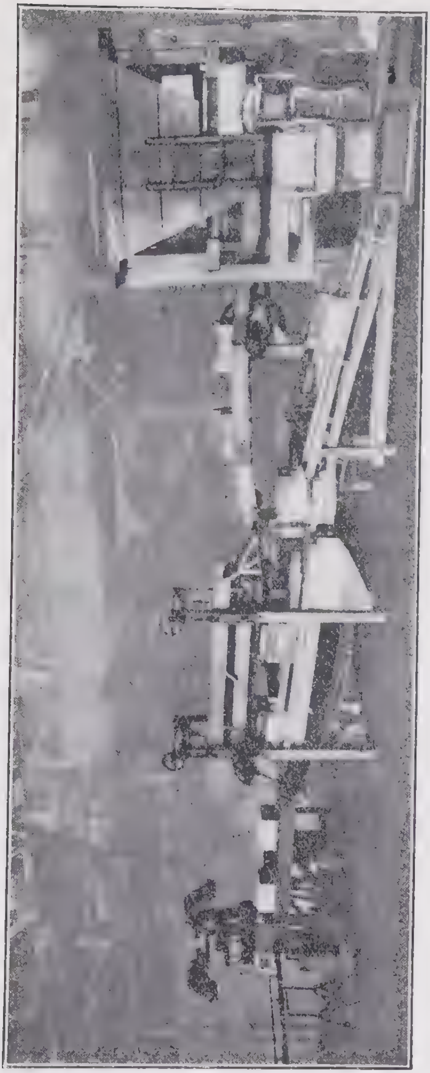

Fig. 14. Prune packing equipment. (Courtesy Anderson-Barngrover Mfg. Co.)

The figures on line c represent the differential plus the boxing cost, which gives in line d the actual selling costs to the broker in 25-pound boxes. Therefore, in order to get the actual selling price on a bulk basis, the boxing cost (one and a half cents) is subtracted as per line e.

## SUMMARY

1. A standard-quality product is of first importance in the future marketing of the Italian prune.

2. The quality must not be an afterthought but must be kept constantly in mind from the growing and harvesting through the packing of the fruit.

3. Although it seems but a small matter, sanitation is essential, and is a big matter from the standpoint of quality.

4. Smaller boxes should be used in the field as large boxes mash the fruit.

5. Lye-dipping of the fruit is not essential, although it increases the drying rate. When using lye, however, the fruit should be thoroughly washed before drying.

6. The Oregon tunnel can be made into a mechanical draft tunnel with controlled temperature, circulation, and humidity.

7. The type of drier is not as essential as a knowledge of the proper relation of the drying factors to obtain *quality*. The proper temperature, humidity, and circulation for the Italian prune have been approximated by experimental work at the Experiment Station. Temperature 150° to 165° F. Circulation 600-750 lineal feet per minute. Humidity 15 to 30 percent.

8. Processing and packing the prune will not remedy mashed, moldy, or dirty fruit.

9. Understand the handling and marketing of the prune. It will make you, as a grower, more capable of intelligently handling your crop.

## ACKNOWLEDGMENTS

Sincere appreciation is expressed to the people and firms who have rendered assistance in making this bulletin complete.

Station Bulletin 206 July, 1924

# Oregon Agricultural College
# Experiment Station

# Studies Relating to the Harvesting and Storage of Apples and Pears

By

HENRY HARTMAN

1885

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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# Studies Relating to the Harvesting and Storage of Apples and Pears

By

HENRY HARTMAN

## INTRODUCTION

It is generally conceded that the ultimate commercial worth of fruits is dependent, in a large measure, upon time and manner of harvesting and general methods of handling. The importance of these phases of fruit production became apparent upon the recognition of the fact that fruits, whether attached to the tree or vine, whether in storage or transit, are living organisms, which carry on life activities and which are influenced by environmental as well as internal factors. Since that time, much attention has been given to the study of both the physiology and the chemistry of fruits. Significant as the discoveries along these lines have been, however, they have left many questions unanswered, and there is still need for much more specific information relative to the activities of fruits during their period of ripening and decay. Only in the light of such information may improved methods and practices of handling be evolved.

**Scope of investigations.** Studies relating to the harvesting and storage of pears at the Oregon Experiment Station have been in progress since 1917. Four reports dealing with various phases of the investigations have already been published. The present report is confined primarily to the results obtained in 1923 by the home station at Corvallis. Observations are confined to fruit grown and harvested under Willamette Valley conditions. Several of the phases treated here are new to these investigations, and all the data presented are being published for the first time. The scope of the work has been enlarged so as to include more generally the winter varieties of pears and certain studies dealing with the handling of apples. In the present discussion no attempt is made to review completely the literature appertaining to the harvesting and storage of fruits.

**Principle of pressure test.** In view of the fact that a great deal of the material presented here relates directly or indirectly to the pressure test, a short account of this test and the principles upon which it is based is not out of place. Though several tests of maturity were considered by the Oregon Experiment Station, it soon became apparent that any reliable test applicable to the pear must be based wholly or in part "upon the physical rather than the chemical contents of the cells," and of the various methods tried the pressure test was the only one to give promise.

This test is based upon the fact that during the growth and ripening of the pear there is a gradual and consistent lowering of the physical resistance to pressure or wounding of the epidermal and cortical region. In the case of Bartlett, the decrease in resistance is close to 2 percent every twenty-four hours. This decrease according to Murneek (1923) is occasioned by several factors, chief among which seem to be (1) increase in the size of the cells, (2) decrease in the thickness of the cell walls, (3) decrease in the amount of cell solids, and (4) wider separation of the stone cells.[1]

To measure the changes in resistance, a simple apparatus now known as the "pressure tester" has been perfected. This instrument merely expresses in convenient units the gradual changes in resistance that take place from time to time. A complete description of the pressure tester and its application is given in Oregon Agricultural Experiment Station Bulletin 186.

## EXPERIMENTAL—PART I. PEARS

### LOSS OF WEIGHT AFTER HARVEST

It is a matter of common knowledge that fruit loses weight following removal from the tree or vine. In extreme cases loss of weight while in storage may amount to as much as 15 percent of the total weight of the fruit. Two factors account for loss of weight in fruits: (1) natural decomposition, and (2) excessive loss of moisture. In the case of winter apples, loss of weight through natural decomposition would not exceed 0.2 to 0.3 percent of the total weight for the entire storage period.[2] It appears, therefore, that most of the loss must be attributed to the latter factor, which in general is governed by (1) relative humidity, (2) aeration, (3) temperature, (4) time of picking, (5) condition of the epidermis, and (6) kind and variety of fruit.

**The relation of humidity to loss of weight in Bartlett pears.** On August 14, one hundred representative specimens of Bartlett pears were gathered and divided into two lots of fifty each. Both lots were placed in an open container, the specimens being unwrapped. Lot 1 was stored at a relative humidity of 52 to 56 percent, while Lot 2 was stored at a relative humidity of 80 to 86 percent. The temperature in each case was 65° F. Both lots were under observation 408 hours, the pears having reached "prime eating" condition during this time. Weighings were made at the beginning and again at the end of the storage period. Table I shows the losses in weight recorded.

TABLE I. THE RELATION OF HUMIDITY TO LOSS OF WEIGHT IN BARTLETT PEARS

| Lot No. | Pressure test | Temperature of storage room (Fahr.) | Relative humidity of storage room | No. of hours in storage | Loss of weight in percents |
|---|---|---|---|---|---|
| | *lbs.* | | | | % |
| 1 | 40.3 | 66° | 52-56 | 408 | 13.9 |
| 2 | 40.3 | 66° | 80-86 | 408 | 1.1 |

The data given in Table I are of primary importance in showing (1) that loss of weight may be a considerable factor in the handling of Bartlett pears, and (2) that insufficient humidity is its chief causal agent. Seemingly, loss of weight can be practically prevented by storage at a relative humidity of 80 to 86 percent. This observation corroborates the results of Magness and Diehl,[2] 1924, who found that loss of weight in winter apples was practically nil at a relative humidity of 85 to 90 percent over a period of five to seven months.

Fruit gathered during a period of low relative humidity may lose considerable weight if left unprotected in the orchard or packing house. Bartlett pears of the first picking showed a loss of nearly four percent when left for four days under the trees. It was found, however, that much of this loss can be eliminated by merely covering the boxes with wet canvas.

**Effect of loss of weight upon the appearance and quality of the fruit.** Excessive loss of weight invariably results in wilting, which seriously impairs the appearance of the fruit. Wilted pears, in the main, have lost their gloss and waxiness, are dull and unattractive, and do not become aromatic. In the case of Bartlett, Anjou and Comice, it was found that a loss of weight of three to four percent was sufficient to cause noticeable wilt. There is no indication, however, that wilted fruit goes down more rapidly, or that its texture and juiciness are impaired to any extent. Fruit in this condition seems to be slightly more resistant to attack of decay organisms.

**Time of picking in relation to loss of weight.** It is a well known fact that fruit picked while in an immature condition wilts more readily than that picked later in the season. This seems to be due to the fact that while the fruit is growing, its lenticels or breathing pores are open and that as the season advances, these become covered over with a layer of cork-like cells[3] which seem to be instrumental in preventing loss of moisture.

To determine the effect of time of picking on the rate at which pears lose weight, Bartlett pears were picked at three different times, during the harvesting season, the first lot being picked on August 14, the second on August 29 and the third on September 14. Pressure test readings were made at the time of each picking. Each lot was accurately weighed and placed in storage for 264 hours at a temperature of 66° F. and a relative humidity of 52 to 56 percent. At the end of the time the lots were again weighed and the percentage of loss of weight computed. Table II gives the percentage of weight lost in each case.

TABLE II. TIME OF PICKING IN RELATION TO LOSS OF WEIGHT IN BARTLETT PEARS

| Lot No. | Date of picking and storing | Pressure test | Temperature of storage room (Fahr.) | Relative humidity | No. of hours in storage | Loss of weight in percents |
|---|---|---|---|---|---|---|
| | | *lbs.* | | | | % |
| 1 | 8/14 | 40.3 | 66° | 52-56 | 264 | 9.7 |
| 2 | 8/29 | 33.0 | 66° | 52-56 | 264 | 6.3 |
| 3 | 9/14 | 25.8 | 66° | 52-56 | 264 | 5.8 |

All things being equal, the rate at which pears lose weight after harvest is greater in the case of those picked early in the season than in the case of those picked later. It is obvious, however, that all pears, whether picked early or late, lose considerable weight when kept at low humidities for any length of time.

**Effect of type of wrappers upon loss of weight.** The material for this test consisted of typical specimens of Bartlett pears gathered on August 29. The pressure test reading on these pears was 31.5 pounds. The specimens were arranged into three lots of equal size. Those of

Lot 1 were stored in an open crate without wrappers. Those of Lot 2 were wrapped in common fruit tissue. Those of Lot 3 were wrapped in commercial oiled paper containing about 4 percent "Tecol." The three lots were placed in storage for 352 hours at a temperature of 66° F. and a relative humidity of 52 to 56 percent. Weighings were made at the beginning and again at the end of the storage period. A summary of the results is given in Table III.

TABLE III. THE EFFECT OF TYPE OF WRAPPERS UPON LOSS OF WEIGHT IN BARTLETT PEARS

| Lot No. | Date of picking and storing | Pressure test | Temperature of storage room (Fahr.) | Relative humidity of storage room | No. of hours in storage | Type of wrap | Loss of weight in percents |
|---|---|---|---|---|---|---|---|
| | | *lbs.* | | | | | % |
| 1 | 8/29 | 31.5 | 66° | 52-56 | 352 | unwrapped | 7.9 |
| 2 | 8/29 | 31.5 | 66° | 52-56 | 352 | common fruit tissue | 6.8 |
| 3 | 8/29 | 31.5 | 66° | 52-56 | 352 | oil wrap | 6.7 |

From these figures it appears that the type of wrappers used had but little effect upon the rate at which the specimens lost weight in storage. It is true that loss of weight was slightly less in the case of both the fruit fiber and oil wraps, but the difference is too small to be of practical significance.

**Rate of loss of weight.** This test was undertaken with the aim of answering the following questions: (1) All factors being equal, do pears after picking, lose weight at a constant rate, or (2) does the rate vary from time to time?

Twelve typical specimens of Bartlett were gathered on August 29. These were kept in storage in an open container at a temperature of 66° F. and a relative humidity of 52 to 56 percent for a period of 16 days. Accurate weighings were made at 9 a.m. each day. The data obtained are given in Table IV. Fig. 1 illustrates graphically the rate at which loss of weight occurred.

TABLE IV. RATE OF LOSS OF WEIGHT IN BARTLETT PEARS

| Date | Weight | Daily loss of weight | Daily loss of weight in percents | Total loss of weight in percents |
|---|---|---|---|---|
| | *grams* | *grams* | % | % |
| Aug. 29 | 2405.5 | | | |
| Aug. 30 | 2391.9 | 13.6 | .56 | .56 |
| Sept. 1 | 2379.6 | 12.3 | .51 | 1.07 |
| Sept. 2 | 2359.0 | 20.6 | .78 | 1.87 |
| Sept. 3 | 2344.8 | 14.2 | .59 | 2.44 |
| Sept. 4 | 2331.7 | 13.1 | .54 | 2.98 |
| Sept. 5 | 2319.2 | 12.5 | .52 | 3.50 |
| Sept. 6 | 2306.6 | 11.6 | .48 | 3.98 |
| Sept. 7 | 2292.8 | 13.8 | .57 | 4.55 |
| Sept. 8 | 2278.8 | 14.0 | .58 | 5.13 |
| Sept. 9 | 2265.5 | 13.3 | .55 | 5.68 |
| Sept. 10 | 2251.6 | 13.9 | .57 | 6.25 |
| Sept. 11 | 2240.2 | 11.4 | .48 | 6.73 |
| Sept. 12 | 2229.4 | 10.8 | .45 | 7.18 |
| Sept. 13 | 2218.3 | 11.1 | .47 | 7.66 |
| Sept. 14 | 2206.7 | 11.6 | .48 | 8.14 |

These pears evidently lost weight at a fairly constant and uniform rate throughout the period of storage. Minor fluctuations occurred from day to day, but as Fig. 1 indicates, these did not cause radical changes in the rate at which the fruit lost weight. Data from other lots of pears in storage indicate that this is a general rule.

## LOSS OF VOLUME AFTER HARVEST

Both growers and dealers are aware of the fact that pears lose volume following removal from the tree. Tightly packed boxes frequently become slack while in storage or in transit, this being a common cause of controversy in the fresh fruit trade. Loss of volume in pears was considered in the present investigations (1) to ascertain the importance of such loss and (2) to consider methods for its prevention.

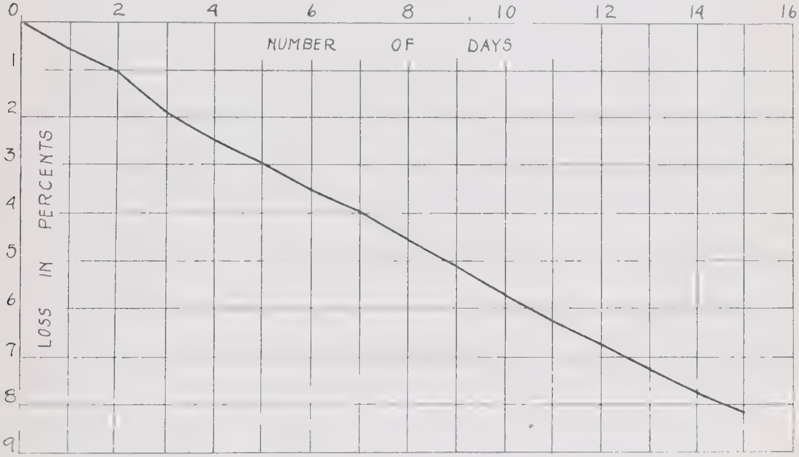

Fig. 1. The rate of loss of weight in Bartlett pears.

**Amount of volume lost.** Three lots of Bartlett pears which had been gathered and stored for the test relating to loss of weight, furnished the data on loss of volume. These, as already indicated, were picked on August 14, August 29, and September 14, and stored at a temperature of 66° F. and a relative humidity of 52 to 56 percent. The volume of each lot was computed at the time of picking and again at the end of the storage period, by immersing the pears in water and measuring the amount of displacement. The weight records of these lots afforded an opportunity to compare loss of volume with loss of weight. Table V shows the loss of volume in percents and also the relationship between the loss of volume and the loss of weight.

TABLE V. COMPARISON OF LOSS OF WEIGHT WITH LOSS OF VOLUME IN BARTLETT PEARS

| Lot No. | Date of picking and storing | Pressure test | Temperature of storage room (Fahr.) | Relative humidity of storage room | No. of hours in storage | Loss of weight in percents | Loss of volume in percents |
|---|---|---|---|---|---|---|---|
| | | lbs. | | | | % | % |
| 1 | 8/14 | 40.3 | 66° | 52-56 | 408 | 13.9 | 14.5 |
| 2 | 8/29 | 33.0 | 66° | 52-56 | 352 | 7.8 | 9.2 |
| 3 | 9/14 | 25.8 | 66° | 52-56 | 264 | 5.8 | 6.2 |

From the data of Table V it appears (1) that loss of volume may be a factor of considerable importance, and (2) that there is a close correlation between loss of volume and loss of weight. Seemingly, every loss of weight is accompanied by a corresponding loss in volume.

**Method of prevention.** Since loss of volume is closely correlated with loss of weight, it is obvious that what will prevent one will also prevent the other, and as already indicated the prevention of loss of weight is primarily a matter of maintaining a fairly high relative humidity at all times.

## AMOUNT OF CROP IN RELATION TO DEGREE OF MATURITY

Considerable difficulty has been encountered in the handling of pears because of rather wide variation in the time of maturity manifested by specimens within the same lot. Dealers and canners, in particular, have often referred to this condition. Since unevenness in ripening takes place among pears picked at the same time and stored under identical conditions, it appears that this condition must occur because all pears from a given orchard are not of the same degree of maturity at the time of picking.

From casual observation it is fairly clear that there is a difference in degree of maturity between fruit from heavily and lightly loaded trees. That from heavily loaded trees appears to be farther advanced. It is usually lighter in color, more glossy in appearance, and somewhat softer in texture. The importance of this apparent difference in maturity was ascertained in the following manner:

On August 15 fruit was selected at random from fifty heavily loaded Bartlett trees in the Oaço orchards at Monroe. At the same time, fruit was selected in a like manner from fifty lightly loaded trees. Pressure test readings and caliper measurements were then made of each lot. This test was repeated on August 24, and again on September 7. The following table gives the results for the three determinations:

AMOUNT OF CROP IN RELATION TO DEGREE OF MATURITY

| Nature of crop | Transverse diameter | Pressure test |
|---|---|---|
| | *in.* | *lbs.* |
| **Test No. 1, August 15.** | | |
| Heavy | 2 7/8 | 38.4 |
| Light | 2 9/16 | 43.8 |
| **Test No. 2, August 24.** | | |
| Heavy | 2 8/16 | 34.9 |
| Light | 2 10/16 | 39.3 |
| **Test No. 3, September 9.** | | |
| Heavy | 2 11/16 | 27.2 |
| Light | 2 14/16 | 32.9 |

As indicated by the pressure test, there is a relationship between the amount of crop present on the trees and the degree of maturity of the fruit, that from heavily loaded trees being relatively more mature than that from lightly loaded trees. This difference seems to obtain throughout the harvest season and is sufficient to account for much of the unevenness in ripening manifested by pears after harvest. Again, as the caliper measurements indicate, the fruit from lightly loaded trees, though considerably less mature, is larger in size. This is significant since in many instances pears are picked according to size. Obviously, where this practice is in vogue, the less mature fruit is often the first to be gathered.

## FACTORS AFFECTING THE PRESSURE TEST

Murneek[3] 1921, mentions certain factors which may affect the pressure test and calls attention to their practical significance. The work of the past season, however, shows that the results obtained with the pressure tester may be affected by several factors which did not receive attention in the previous reports.

**Temperature of the fruit.** The recent work of Hawkins and Sando[5] shows that in the case of cherries and certain cane fruits, the resistance of the epidermis and cortical region to mechanical injury varies more or less with the temperature of the fruit. The resistance, it seems, varies in inverse proportion to the temperature. Obviously, if this situation obtains in the case of pears, temperature of the fruit should have influence upon the pressure test. Data on this point were furnished by the following experiment:

On August 29, forty typical specimens of Bartlett were gathered and placed in a common ice-box. At the end of six hours the temperature of this fruit was 51° F. Pressure test readings were then made, and the pears were placed in the Freas electric oven, where their temperature soon registered 97° F. Pressure test readings were again made while the fruit was at this temperature. Table VI gives the results obtained.

TABLE VI. THE EFFECT OF THE TEMPERATURE OF THE FRUIT ON THE PRESSURE TEST

| Date | Temperature of fruit (Fahr.) | Pressure test |
|---|---|---|
| | | *lbs.* |
| August 29 | 51° | 35.0 |
| August 29 | 97° | 31.6 |

Resistance to pressure, obviously, fluctuates with the temperature of the fruit at the time the test is made. In this case, an increase in temperature of 46° F. was accompanied by a decrease in resistance of 3.4 pounds. The significance of this factor is apparent when it is borne in mind (1) that a difference of 3.4 pounds in the pressure test reading of Bartlett pears means a difference of approximately 7 days in the time of picking, and (2) that the temperature of fruit in the orchard may vary as much as 50 degrees F. in the course of 24 hours.

**Removal of part of the crop.** Preliminary observations on Bartlett during the season of 1923 showed that the removal of a portion of the crop interferes with the pressure test for the remainder of the crop. When three-fourths of the pears were removed at mid-season, those remaining on the trees failed to show the usual decrease in resistance for some time following. Up to the time this picking was made, the entire crop had shown an average decrease of about one-half pound per day, but following this picking the decrease noted was less than one pound in ten days.

Several interesting questions are suggested by this behavior. (1) Is the part of the crop remaining on the trees actually ripening in spite of its failure to show a material decrease in resistance or is it merely in a state of suspended animation? (2) Are other varieties subject to this irregularity? (3) Does this condition render the pressure test ineffective as an indicator of maturity for the later pickings?

The following test on Anjou and Comice throws light upon these questions: On September 25, about three-fourths of the crop was removed from certain Anjou trees. The average pressure test reading at this time was 19.5 pounds, and for 32 days previous to this picking Anjou had shown an average decrease in resistance of nearly one-half pound per day. Pickings of the remainder of the crop were made on September 28, October 1, October 5, and October 9. Pressure tests were made and the pears from each picking were placed in storage at a temperature of 66° F. and a relative humidity varying from 80 to 86 percent. This experiment was repeated with Comice, the major portion of the crop being removed on October 5, and subsequent pickings being made on October 9, October 13, and October 19. From September 17 to October 5, the Comice had shown an average decrease in resistance of about four-tenths pound per day. Check trees of both varieties were left untouched so that a comparison of the relative decrease in resistance could be obtained. Tables VII and VIII give most of the data obtained in the course of this experiment.

TABLE VII. REMOVAL OF PART OF CROP IN RELATION TO SUBSEQUENT PRESSURE TESTS IN ANJOU PEARS

| Lot No. | Date of picking and storing | Pressure test | Temperature of storage room (Fahr.) | Relative humidity of storage room | Date of prime eating condition | No. of days to attain prime eating condition |
|---|---|---|---|---|---|---|
| | | *lbs.* | | | | |
| 1 | 9/25 | 19.5 | 66° | 80-86 | 10/31 | 36 |
| 2 | 9/28 | 19.1 | 66° | 80-86 | 10/31 | 33 |
| 3 | 10/1 | 19.3 | 66° | 80-86 | 11/1 | 31 |
| 4 | 10/5 | 19.4 | 66° | 80-86 | 11/1 | 27 |
| 5 | 10/9 | 18.9 | 66° | 80-86 | 11/1 | 23 |

TABLE VIII. REMOVAL OF PART OF CROP IN RELATION TO SUBSEQUENT PRESSURE TESTS IN COMICE PEARS

| Lot No. | Date of picking and storing | Pressure test | Temperature of storage room (Fahr.) | Relative humidity of storage room | Date of prime eating condition | No. of days to attain prime eating condition |
|---|---|---|---|---|---|---|
| | | *lbs.* | | | | |
| 1 | 10/5 | 18.2 | 66° | 80-86 | 11/3 | 28 |
| 2 | 10/9 | 18.0 | 66° | 80-86 | 11/2 | 24 |
| 3 | 10/13 | 18.1 | 66° | 80-86 | 11/1 | 19 |
| 4 | 10/19 | 17.7 | 66° | 80-86 | 11/1 | 13 |

From these data it appears that removal of a major portion of the crop affects the pressure test for the remainder. After three-fourths of the crop had been removed, in the case of Anjou, the effect was so marked that the remainder of the pears showed a total decrease in resistance of only six-tenths of a pound in 14 days, while those on the check trees from which no fruit had been removed showed a total decrease in resistance of 5.6 pounds during the same period. Specimens of Comice showed a total decrease in resistance of only five-tenths of a pound in 13 days, while fruit from the check trees of this variety showed a total decrease of 4.1 pounds.

But even though the removal of a portion of the crop does arrest or retard the usual decrease in resistance, there is indication that this has no relation to the ripening process. The data from the storage tests seem to show that while there is no material decrease in resistance for some time following removal of a portion of the crop, the pears are ripening at the usual rate. Specimens of Anjou picked on September 25 required 35 days to reach "prime" eating condition, those picked on October 9 required only 23 days, this in spite of the fact that the total decrease in resistance between these pickings was only six-tenths of a pound. Specimens of Comice picked on October 5 required 28 days to reach maturity, while those picked on October 19 required only 13 days. In this case, the total decrease in resistance between picking dates was only five-tenths of a pound.

Thus it would seem that after a goodly portion of the crop has been removed, the pressure test is no longer an accurate indicator of maturity for the fruit that remains on the trees. This has practical significance in cases where the crop is disposed of in more than one picking. It is suggested that in such cases, the theoretical rather than the actual decrease in resistance be used as the indicator. If, for example, the average rate of decrease in resistance has been four-tenths of a pound a day for some time prior to the first picking, it can be assumed that this indicates the rate of maturity for the entire season.

**Turgidity of the fruit.** Murneek, 1921, observed that following harvesting, pears frequently register an increase in resistance instead of the expected decrease due to advancing maturity.[4] Bartlett pears picked on August 6, for example, gave a pressure test reading 33.0 pounds six hours after picking and 36.0 pounds 36 hours after picking. This seemed to be especially true of pears of the early pickings.

Though not fully understood, this irregularity in the behavior of resistance following the time of picking appears to be associated with the turgidity of the fruit. It seems possible that the increase in resistance is due to the wilted or leathery nature of the epidermis and cortical tissue following loss of moisture. Magness and Burroughs, 1923, found that in all varieties of apples the skin becomes tougher after the fruit goes into storage and concluded that this condition is probably due to lessened turgidity.[6]

The data relative to the effect of turgidity on the pressure test was furnished in part by two lots of Bartlett pears gathered on August 24. Pressure test readings were made at picking time and both lots were then placed in storage at a temperature of 66° F. Lot 1 was subjected to a relative humidity of 80 to 86 percent, while Lot 2 was kept at a relative humidity of 52 to 56 percent. At the end of 36 hours, both lots were removed from storage and again subjected to the pressure test. Table IX gives the results obtained.

TABLE IX. TURGIDITY OF THE FRUIT IN RELATION TO THE PRESSURE TEST

| Lot No. | Temperature of storage room (Fahr.) | Relative humidity of storage room | Pressure test at picking time | Pressure test 36 hours later |
|---|---|---|---|---|
| | | | *lbs.* | *lbs.* |
| 1 | 66° | 80-86 | 35.9 | 33.9 |
| 2 | 66° | 52-56 | 35.7 | 36.4 |

Apparently, when pears are kept at high humidity where loss of moisture is practically nil and turgidity is not lessened, the resistance shows the expected decrease. When they are subjected to low humidity, however, where loss of moisture and lessened turgidity are the rule, an increase in resistance is noted.

**Loss of turgidity while on the trees.** It has been noted several times that during periods of drought and low humidity, pears attached to the trees often fail to show the usual decrease in resistance. In fact, during the dry spell of 1922, Anjou pears in the Oaco orchards at Monroe actually showed an increase in resistance from day to day, for a considerable period of time. Fruit of the same variety in the orchard of the Corvallis Orchard Company displayed the same tendency in 1923. On September 15, these pears gave a test of 30.1 pounds. Five days later they gave a test of 31.0 pounds, this in spite of the fact that they were rapidly becoming lighter in color and gave evidence of approaching maturity. Due to heavy pruning and abundant moisture in spring, the trees in this orchard were covered with unusually heavy foliage, which at this time, gave unmistakable evidence of lack of moisture. On September 23 and 24, however, a considerable amount of rain fell. The drought came to an end and the leaves immediately regained their turgidity. Pressure tests on the fruit made on September 25, gave a reading of 23.1 pounds, showing a decrease of 7.9 pounds in five days.

Here, again, there seems to be a correlation between the turgidity of the fruit and the response from the pressure tester. During dry periods, several factors may contribute to lessened turgidity: (1) the fruit itself may give up moisture to the air; (2) the supply of moisture from the soil is apt to be limiting; and (3) the leaves may actually draw water from the fruit.[7]

The results of the following tests are interesting in this connection. Two lots of Anjou pears were gathered on September 15. The specimens of Lot 1 were gathered in the usual way, while those of Lot 2 were gathered with the leaves and spurs attached. Pressure test readings of each lot were made at the time of picking. Both lots were then placed in storage at a temperature of 66° F. and a relative humidity of 80 to 86 percent. At the end of 36 hours, both lots were removed from storage, and pressure test readings were again made. Table X gives the data from these readings.

TABLE X. APPARENT EFFECT OF LEAVES ON TURGIDITY

| Lot No. | Treatment | Temperature of storage room (Fahr.) | Relative humidity of storage room | Pressure test at picking time | Pressure test 36 hours later |
|---|---|---|---|---|---|
| | | | | *lbs.* | *lbs.* |
| 1 | Stored without leaves | 66° | 80-86 | 31.6 | 30.0 |
| 2 | Stored with leaves attached | 66° | 80-86 | 31.3 | 33.1 |

The pears of Lot 1, as might be expected, show the usual decrease in resistance, there being a reduction of 1.6 pounds during the 36 hours. Those of Lot 2, on the other hand, show an increase of 1.3 pounds for the same period. The leaves, apparently, continued to draw moisture from the fruit and thus lowered its turgidity.

**The effects of paring.** Magness and Burroughs, 1923, found an interesting comparison between the relative toughness of the peel in apples.[6] These authors report a wide variation among the different varieties between the pressure test readings of pared and unpared fruit; Baldwin at picking time showing a difference in resistance of 3.4 pounds; Rome, a difference of 4.52 pounds; and Yellow Newtown, 8.00 pounds. The difference in resistance between pared and unpared fruit seems to increase as the fruit remains in storage, and in order to obtain a more indicative test of the degree of hardness of the flesh, it is recommended that the fruit be pared before pressure test readings are made.

When the pressure test is being applied to determine the time of picking, however, paring has advantage only when it is known that this treatment lessens the amount of variation between individual determinations. A constant difference of 1.5 pounds between pared and unpared fruit would have no bearing upon the test; but, on the other hand, if differences in thickness and texture of the epidermis add to the variability between individual determinations, then paring of the specimens might give more uniform results.

Information on this point was furnished by 21 specimens of Bartlett gathered on August 22. Four pressure test determinations were made on opposite sides of each specimen, two upon pared surface and two upon unpared surface. The amount of variation was recorded and compared as shown in Table XI.

TABLE XI. VARIATION BETWEEN PRESSURE TEST DETERMINATIONS MADE ON PARED AND UNPARED SURFACES OF BARTLETT PEARS

| No. | Readings on unpared surface | Variation | Readings on pared surface | Variation |
|---|---|---|---|---|
| | *lbs.* | *lbs.* | *lbs.* | *lbs.* |
| 1 | 39-37 | 2 | 35-33 | 2 |
| 2 | 37-40 | 3 | 35-34 | 1 |
| 3 | 37-39 | 2 | 35-37 | 2 |
| 4 | 38-39 | 1 | 37-39 | 2 |
| 5 | 35-39 | 4 | 35-33 | 2 |
| 6 | 39-39 | 0 | 35-37 | 2 |
| 7 | 39-37 | 2 | 38-35 | 3 |
| 8 | 37-40 | 3 | 35-36 | 1 |
| 9 | 37-37 | 0 | 35-37 | 2 |
| 10 | 39-37 | 2 | 35-36 | 1 |
| 11 | 38-38 | 0 | 37-35 | 2 |
| 12 | 39-39 | 0 | 39-38 | 1 |
| 13 | 35-34 | 1 | 34-34 | 0 |
| 14 | 39-40 | 1 | 37-36 | 1 |
| 15 | 38-38 | 0 | 36-36 | 0 |
| 16 | 39-37 | 2 | 37-36 | 1 |
| 17 | 38-37 | 1 | 37-37 | 0 |
| 18 | 37-37 | 0 | 33-33 | 0 |
| 19 | 35-35 | 0 | 35-36 | 1 |
| 20 | 36-36 | 1 | 35-35 | 0 |
| 21 | 38-37 | 1 | 33-33 | 0 |
| | Total variation | 26 | | 25 |

It is noticeable that while the unpared surfaces gave a slightly higher resistance throughout, the total amount of variation among individual determinations made on such surfaces was not materially greater than that found among the determinations recorded on pared surfaces. If these results are indicative of the general situation, practically nothing is gained by paring so far as Bartlett is concerned. Similar tests with Anjou, Comice, Howell, and others indicate that this rule holds true for the clear skinned varieties in general.

**Effects of russeting.** Apparently, the kind of russeting such as sometimes occurs in Bartlett, Anjou, and Comice has but little effect upon the pressure test. In the case of such varieties as Bosc and Winter Nelis, however, russeting may affect resistance in a material way. This is shown by Table XII, which represents variation in readings manifested by Winter Nelis pears from the same tree on October 27.

TABLE XII. EFFECT OF RUSSET ON RESISTANCE IN WINTER NELIS PEARS

| Lot No. | Condition of epidermis | Pressure test |
|---|---|---|
| | | *lbs.* |
| 1 | Pared | 21.2 |
| 2 | Clear | 26.4 |
| 3 | Heavily russeted | 29.1 |

It will be noted that the average difference between the determinations made on clear and russeted surfaces is 2.7 pounds. When it is borne in mind that the average daily rate of decrease in resistance in Winter Nelis is less than 0.3 pound, the significance of this variation is apparent and it is obvious that erroneous conclusions will result unless it is taken into account. Again, this factor complicates the situation in that the increased resistance occasioned by russeting varies with the intensity of the russet. In this particular case, differences varying from less than one pound to nearly three pounds were recorded. The difficulty of making allowance for the russet is at once apparent, and it is suggested that clear skinned specimens be used whenever possible, and when these cannot be obtained it is perhaps best to pare the fruit as indicated under another caption.

**Effect of red color.** Zschokke, 1897, found that with the exposure of fruits to the sun, there is a thickening of the cuticle and subepidermal area.[8] Magness and Diehl, 1924, found that in apples, there is a distinct variation in the thickness of the subepidermal region, the heavily blushed sides of Rome Beauty showing 8 to 10 layers of cells in this portion whereas the unblushed part shows but six layers.[2] These authors note, also, that blushed surfaces are harder in texture. Murneek, 1923, calls attention to the fact that the pigmented part of pears offers greater resistance to wounding than do the green portions.[1]

Table XIII shows the possible effect of a red blush on the pressure test. Specimens of Bartlett gathered on August 18 were used for this test. Pressure test determinations were made on both the blushed and uncolored surfaces of the same specimens.

TABLE XIII. THE RELATION OF COLOR TO RESISTANCE IN BARTLETT PEARS

| Lot No. | Condition of the epidermis | Pressure test |
|---|---|---|
| | | *lbs.* |
| 1 | Blushed | 41.2 |
| 2 | Uncolored | 38.7 |

Evidently, the difference in resistance offered by blushed and uncolored surfaces of the same specimens is considerable. Tests at various times during the season showed about the same relative difference. Anjou and Comice gave very much the same results. As in the case of russet, the resistance varies somewhat with the intensity of the blush, a deep blush offering considerably more resistance than one less intensely colored.

**Relative seasonal decrease in resistance of cortex and epidermal regions.** Nine separate pickings of Comice were made during the harest season of 1923. Comprehensive pressure tests of both pared and unpared specimens of each picking were made and recorded. The data obtained in this manner afford an opportunity to compare the seasonal changes in resistance manifested by both the cortex and epidermal regions. Table XIV gives these data.

TABLE XIV. THE RELATIVE SEASONAL DECREASE IN RESISTANCE OF THE CORTEX AND EPIDERMAL REGIONS OF COMICE PEARS

| Lot No. | Date of picking | Pressure test, unpared specimens | Pressure test, pared specimens | Difference in resistance |
|---|---|---|---|---|
| | | *lbs.* | *lbs.* | *lbs.* |
| 1 | 9/17 | 25.7 | 21.2 | 4.5 |
| 2 | 9/21 | 24.3 | 20.2 | 4.1 |
| 3 | 9/25 | 23.0 | 20.0 | 3.0 |
| 4 | 9/28 | 21.6 | 18.8 | 2.8 |
| 5 | 10/1 | 19.1 | 16.0 | 3.1 |
| 6 | 10/5 | 18.2 | 15.3 | 2.9 |
| 7 | 10/9 | 18.0 | 15.2 | 2.8 |
| 8 | 10/13 | 17.3 | 14.8 | 2.5 |
| 9 | 10/19 | 16.5 | 14.2 | 2.2 |

Obviously, less resistance was recorded for the pared fruit in each case, but the difference in resistance between the pared and the unpared fruit became less and less as the season progressed, being 4.5 pounds at the time of the first picking, and 2.2 pounds at the time of the last picking. The epidermal region, in other words, shows a greater amount of seasonal decrease in resistance than does the cortex, and since the efficiency of the pressure test is dependent primarily upon the range of resistance manifested, unpared fruit should give a more indicative test when the above condition obtains.

## GENERAL INDICATORS OF MATURITY IN PEARS

The general indicators of maturity in pears again received attention during the present investigations, and a brief digest of the observations is given here.

**Ease of separation from the spur.** Ease of separation from the spur does not seem to be a reliable indicator of maturity in pears. This factor, seemingly, is associated with the moisture conditions of the tree and fruit. When moisture is abundant and turgidity is high, most pears separate quite readily from the spurs though they may be comparatively green. But when the moisture is limiting and turgidity is below normal, the fruit tends to cling regardless of maturity. This is especially true during the early part of the harvest season.

**Size of the fruit.** Though often resorted to in actual practice, size of fruit is not an indicator of maturity according to findings in these investigations. The larger specimens are usually no riper than are the smaller ones; in fact, as already pointed out, there are instances where the smaller specimens in the same orchard are actually much riper than are the larger ones.

**Ripening of imperfect specimens.** With most varieties of pears, wormy or otherwise imperfect specimens often fall to the ground and ripen considerably in advance of the normal crop. This has proved to be a fairly reliable indicator of maturity. So long as the imperfect specimens fall to the ground and merely shrivel up without ripening, it is safe to assume that the normal fruit has not reached picking maturity, but as soon as these specimens are observed to turn yellow and soften up without undue shriveling the bulk of the crop can generally be picked without danger of sacrifice in quality.

**Color of the seeds.** In some of the fruit districts of eastern United States the color of the seed is often employed as an indicator of maturity. In Oregon, however, this factor has proved to be extremely unreliable, the color of the seeds varying widely with the season, moisture conditions, and age of the trees.

**Changes of the ground color.** Two distinct color elements may be associated with the pear. First, there is the blush or "overcolor" which seemingly is brought on by factors other than those associated with ripening and which has, therefore, no value as an indicator of maturity. Second, there is the ground or "undercolor," which, during the period of maturity usually changes from a dull green to a light green or yellow, and which may be of considerable value in determining time of picking, especially in the clear skinned varieties such as Clapp's Favorite, Bartlett, Howell, Anjou, and Comice. The change in ground color in most pears takes place in a rather characteristic manner. The surface for the most part becomes lighter in color with the exception of a small area immediately surrounding each lenticel or breathing pore. This gives the pear a more or less speckled or dotted appearance. In the case of Bartlett, the speckling usually occurs when the pressure test registers around 38 pounds. This would mean that the first picking of pears for eastern shipment may be made ordinarily from 5 to 8 days following the appearance of the green dots.

**Nature of the bloom.** Most of the deciduous fruits during the period of growth and maturity are covered with whitish "bloom" which gives the fruit a characteristic bluish or gray tinge. In the case of pears, the bloom is usually more or less insignificant yet may be of some value as an indicator of maturity. During the period of growth, pears of the clear skinned type have a rather dull appearance because of this bloom, but as the fruit approaches maturity, a portion of the bloom disappears and the pear takes on a brighter and waxier finish. This is noticeable especially in the case of Bartlett.

## RELATION OF TIME OF PICKING TO QUALITY AND TIME OF RIPENING

Representative lots of Anjou, Comice, Winter Nelis, and Bartlett were gathered at intervals of 3 to 5 days during the season of 1923. Pressure test readings were made of each lot and the lots were all placed in storage at a temperature of 66° F. and a relative humidity of 52 to 56 percent. The specimens were wrapped in common fruit tissue and packed in open containers. Careful observations were made from time to time with the aim of ascertaining, so far as possible, (1) the effects of time of picking on quality and time of ripening, and (2) the proper time of harvesting as indicated by the pressure tester.

**Anjou.** As shown in Table XV, ten separate pickings of Anjou were made during the season of 1923, the first on August 29 and the final on October 5. It will be noted that a considerable difference was registered in the time required for the fruit of the various pickings to reach prime eating condition, that of the first requiring 54 days, and that of the last, only 26 days. This is a rather significant observation. As Table XV shows, the pears from the early pickings developed inferior quality in storage. They were undersized for the variety, and displayed more or less wilt. They were somewhat astringent, lacked in sweetness, and tended to ripen unevenly. Those picked late in the season lacked a little in juiciness, but in the main were of good quality. It appears from these data that Anjou has a comparatively long picking season, since all the fruit gathered between September 4 and September 28 developed full Anjou characteristics and held up remarkably well. Obviously, there was a gradual reduction in resistance throughout the harvest season, the pears of the first picking registering a pressure test of 33.0 pounds and all subsequent pickings showing an average daily decrease of 0.4 pound. So far as these results indicate, Anjou in the Willamette Valley may be safely picked when the pressure test readings are between 24 and 19 pounds.

**Comice.** Beginning with September 17, and ending with October 19, nine separate pickings of Comice were made. These were handled as indicated in the case of Anjou. The data on Comice, which in general corroborate those obtained with Anjou, are given in Table XVI. As before, the fruit of the early pickings was inferior in quality, showed considerable wilt, and was undersized.[12] Fruit of these pickings required considerably longer to reach edible maturity in storage. Late picked fruit lacked somewhat in juiciness and went down rapidly due to core rot. Comice, unlike Anjou, seems to have a rather short harvesting period. Only the pears picked between October 1 and October 9 developed real Comice quality. Comice, like other varieties, shows a gradual decrease in resistance during the season, the pressure test reading at the time of the first picking being 25.7 pounds and only 16.5 pounds at the time of the last picking. Indications are that Willamette Valley Comice should be gathered when the pressure test registers between 20 and 18 pounds.

**Winter Nelis.** Eight separate pickings of Winter Nelis were made. These were handled in the same manner as were Anjou and Comice. The picking dates and the complete data obtained are given in Table

TABLE XV. THE RELATION OF TIME OF PICKING TO THE QUALITY AND TIME OF RIPENING OF ANJOU PEARS

| Lot No. | Date of picking and storing | Pressure test | Temperature of storage room (Fahr.) | Relative humidity of storage room | Date of prime eating condition | No. of days to attain prime eating condition | Condition at maturity |
|---|---|---|---|---|---|---|---|
| | | *lbs.* | | | | | |
| 1 | 8/29 | 33.0 | 66° | 80-86 | 10/22 | 54 | Considerably undersized. Considerably wilted. Juicy but more or less astringent. Lacking in sweetness and character. No aroma. Tendency to ripen unevenly. No core rot. No scald. |
| 2 | 9/7 | 29.6 | 66° | 80-86 | 10/25 | 48 | Considerably undersized. More or less wilted. Not waxy. Juicy but lacking in sweetness and character. No aroma. No core rot. No scald. |
| 3 | 9/11 | 27.2 | 66° | 80-86 | 10/29 | 48 | More or less undersized. Slightly wilted. Not waxy. Juicy but lacking somewhat in sweetness and character. Quality better than that of Lots 1 and 2. Slightly aromatic. No core rot. No scald. |
| 4 | 9/14 | 25.0 | 66° | 80-86 | 10/30 | 46 | Slightly undersized. Not wilted. More or less waxy. Juicy and fairly sweet. Quality better than that of Lot 3. Aromatic. No core rot. No scald. |
| 5 | 9/17 | 23.2 | 66° | 80-86 | 10/31 | 44 | Practically full sized. Not wilted. Juicy and sweet with full Anjou quality. Good waxy appearance. Ripened evenly. Aromatic. No core rot. No scald. |
| 6 | 9/21 | 21.1 | 66° | 80-86 | 10/31 | 40 | Practically full sized. Not wilted. Juicy and sweet with full Anjou quality. Good waxy appearance. Ripened evenly. Aromatic. No core rot. No scald. |
| 7 | 9/25 | 19.1 | 66° | 80-86 | 10/31 | 36 | Full sized. Not wilted. Juicy and sweet with full Anjou quality. Good waxy appearance. Ripened evenly. Aromatic. No core rot. No scald. |
| 8 | 9/28 | 18.6 | 66° | 80-86 | 10/31 | 33 | Full sized. Not wilted. Juicy and sweet with full Anjou quality. Good waxy appearance. Ripened evenly. Aromatic. No core rot. No scald. |
| 9 | 10/1 | 18.0 | 66° | 80-86 | 10/31 | 30 | Full sized. Not wilted. Juicy and sweet with full Anjou quality. Good waxy appearance. Ripened evenly. Aromatic. No core rot. No scald. |
| 10 | 10/5 | 17.2 | 66° | 80-86 | 10/31 | 26 | Full sized. Not wilted. Slightly less juicy than previous lots, but sweet and of good quality. Good waxy appearance. Ripened evenly. Aromatic. No core rot. No scald. |

XVII. Here again the results in general are very similar to those of other varieties. Fruit of the early pickings required much more time to ripen and was inferior in quality and other respects. That of the very late pickings lacked somewhat in juiciness. As in the case of Anjou, this variety seems to have a long picking season, excellent quality resulting from all pears picked between October 1 and October 20. Though of a less indicative nature, Winter Nelis showed the usual decrease in resistance during the season, registering 35.8 pounds on September 22 and 26.4 pounds on October 27. The results of this test indicate that Winter Nelis should be gathered when the pressure tester indicates a resistance of 33 to 29 pounds. This is assuming that fairly clear skinned specimens are used in making the test. When russeted fruit has to be used and the specimens are pared, the test should read between 28 and 24 pounds.

**Bartlett.** Table XVIII gives the results obtained with nine pickings of Bartlett, the first being made on August 18 and the last on September 18. The data given here correspond very closely with those previously given for this variety in other reports. In general, fruit gathered at

TABLE XVI. THE RELATION OF TIME OF PICKING TO THE QUALITY AND TIME OF RIPENING OF COMICE PEARS

| Lot No. | Date of picking and storing | Pressure test | Temperature of storage room (Fahr.) | Relative humidity of storage room | Date of prime eating condition | No. of days to attain prime eating condition | Condition at maturity |
|---|---|---|---|---|---|---|---|
| | | lbs. | | | | | |
| 1 | 9/17 | 25.7 | 66° | 80-86 | 11/9 | 53 | Considerably undersized. Considerably wilted. Juicy but astringent and lacking in sweetness. Unmarketable. Not waxy. Not aromatic. No core rot. No scald. Tendency to ripen unevenly. |
| 2 | 9/21 | 24.3 | 66° | 80-86 | 11/8 | 46 | Considerably undersized. Considerably wilted. Juicy but astringent, and lacking in sweetness. Unmarketable. Not waxy. Not aromatic. No core rot. No scald. Tendency to ripen unevenly. |
| 3 | 9/25 | 23.0 | 66° | 80-86 | 11/7 | 43 | More or less undersized. Slightly wilted. Juicy but somewhat astringent and lacking in sweetness. Quality somewhat better than that of previous lots. Unmarketable. Not waxy. Not aromatic. No core rot. No scald. |
| 4 | 9/28 | 21.6 | 66° | 80-86 | 11/7 | 41 | Slightly undersized. Slightly wilted. Juicy but lacking somewhat in sweetness. Quality fairly good. Marketable. Not very waxy. Slightly aromatic. No core rot. No scald. |
| 5 | 10/1 | 19.1 | 66° | 80-86 | 11/4 | 35 | Slightly undersized. Slightly shriveled. Juicy, sweet and of good quality. Not very waxy. Slightly aromatic. No core rot. No scald. |
| 6 | 10/5 | 18.2 | 66° | 80-86 | 11/3 | 28 | Full sized. Not wilted. Juicy and sweet with full Comice quality. Good waxy appearance. Aromatic. No core rot. No scald. |
| 7 | 10/9 | 18.2 | 66° | 80-86 | 11/3 | 25 | Full sized. Not wilted. Juicy and sweet with full Comice quality. Good waxy appearance. Aromatic. No core rot. No scald. |
| 8 | 10/13 | 17.3 | 66° | 80-86 | 11/2 | 20 | Full sized. Not wilted. Less juicy than previous lots, but sweet and of good quality. Good waxy appearance. Aromatic. About 31 percent core rot. No scald. |
| 9 | 10/19 | 16.5 | 66° | 80-86 | 11/1 | 13 | Full sized. Not wilted. Much less juicy than previous lots. Sweet but more or less insipid. Good waxy appearance. Aromatic. Tendency to go down rapidly. One hundred percent core rot. No scald. |

mid-season develops the highest quality. Late picked fruit, while suitable for drying and canning, does not hold up sufficiently long for distant shipment in the fresh state. Fruit picked very late in the season develops more or less core rot. The average reduction in resistance of approximately 0.5 pound per day was maintained throughout the season of 1923. The recommendation of Murneek to the effect that Bartlett pears should be picked when the pressure test registers between 35 and 25 pounds was sustained by this test.

TABLE XVII. THE RELATION OF TIME OF PICKING TO THE QUALITY AND TIME OF RIPENING OF WINTER NELIS PEARS

| Lot No. | Date of picking and storing | Pressure test | Temperature of storage room (Fahr.) | Relative humidity of storage room | Date of prime eating condition | No. of days to attain prime eating condition | Condition at maturity |
|---|---|---|---|---|---|---|---|
| | | *lbs.* | | | | | |
| 1 | 9/22 | 35.8 | 66° | 80-86 | 11/1 | 41 | Considerably undersized. Slightly wilted. Juicy but more or less puckery. Only fair in quality. No core rot. No scald. |
| 2 | 9/25 | 34.9 | 66° | 80-86 | 11/2 | 38 | More or less undersized. Slightly wilted. Juicy but more or less insipid and slightly puckery. Quality slightly better than that of Lot 1. No core rot. No scald. |
| 3 | 9/29 | 33.7 | 66° | 80-86 | 11/3 | 35 | Slightly undersized. Not wilted. Juicy and fairly sweet. Quality good. No core rot. No scald. |
| 4 | 10/2 | 33.0 | 66° | 80-86 | 11/5 | 32 | Slightly undersized. Not wilted. Juicy and sweet with full Winter Nelis quality. No core rot. No scald. |
| 5 | 10/6 | 32.6 | 66° | 80-86 | 11/7 | 31 | Full sized. Not wilted. Juicy and sweet with full Winter Nelis quality. No core rot. No scald |
| 6 | 10/13 | 30.0 | 66° | 80-86 | 11/10 | 28 | Full sized. Not wilted. Juicy and sweet with full Winter Nelis quality. No core rot. No scald. |
| 7 | 10/20 | 28.8 | 66° | 80-86 | 11/13 | 24 | Full sized. Not wilted. Slightly less juicy than previous lots. Sweet and of very good quality. No core rot. No scald. |
| 8 | 10/27 | 26.4 | 66° | 80-86 | 11/16 | 20 | Full sized. Not wilted. Slightly less juicy than previous lots. Sweet and of very good quality. No core rot. No scald. |

## PRESENT STATUS OF THE PRESSURE TEST

The pressure tester has been in use for several seasons in the pear districts of Oregon and elsewhere and in general has given satisfactory results, not only as an indicator of picking maturity but as an index of the condition of fruit in storage. There is but little doubt that the pressure test intelligently administered would prevent many of the losses incident to the harvesting and handling of pears. It is now clear, however, that the pressure tester can be efficient only when operated by someone with more or less technical training and who is willing to make a study of the factors involved. Promiscuous use of this apparatus can but lead to erroneous conclusions.

TABLE XVIII. THE RELATION OF TIME OF PICKING TO THE QUALITY AND TIME OF RIPENING IN BARTLETT PEARS

| Lot No. | Date of picking and storing | Pressure test | Temperature of storage room (Fahr.) | Relative humidity of storage room | Date of prime eating condition | No. of days to attain prime eating condition | Condition at maturity |
|---|---|---|---|---|---|---|---|
| | | *lbs.* | | | | | |
| 1 | 8/18 | 38.3 | 66° | 80-86 | 9/2 | 15 | Somewhat undersized. Not wilted. Juicy but slightly astringent and lacking in sweetness. Waxy. Aromatic. No core rot. No scald. Slight tendency to go down after ripening. |
| 2 | 8/20 | 37.2 | 66° | 80-86 | 9/3 | 14 | Somewhat undersized. Not wilted. Juicy but slightly astringent and lacking in sweetness. Waxy. Aromatic. No core rot. No scald. Slight tendency to go down after ripening. |
| 3 | 8/24 | 35.5 | 66° | 80-86 | 9/6 | 13 | Somewhat undersized. Not wilted. Juicy and fairly sweet. Quality somewhat better than that of previous lots. Good waxy appearance. Aromatic. No core rot. No scald. Slight tendency to go down after ripening. |
| 4 | 8/29 | 33.0 | 66° | 80-86 | 9/8 | 10 | Slightly undersized. Not wilted. Juicy and sweet. Quality better than that of previous lots. Good waxy appearance. Aromatic. No core rot. No scald. |
| 5 | 9/1 | 31.5 | 66° | 80-86 | 9/10 | 9 | Apparently full sized. Not wilted. Juicy and sweet with full Bartlett quality. Good waxy appearance. Aromatic. No core rot. No scald. |
| 6 | 9/7 | 28.1 | 66° | 80-86 | 9/15 | 8 | Full sized. Not wilted. Juicy and sweet with full Bartlett quality. Good waxy appearance. Aromatic. No core rot. No scald. |
| 7 | 9/11 | 26.0 | 66° | 80-86 | 9/19 | 7 | Full sized. Not wilted. Slightly less juicy than previous lots but of good quality. Good waxy appearance. Aromatic. No core rot. No scald. |
| 8 | 9/14 | 24.8 | 66° | 80-86 | 9/20 | 6 | Full size. Not wilted. Less juicy than previous lots. Sweet but more or less insipid. Flesh slightly granular. Good waxy appearance. Aromatic. About 5 percent core rot. No scald. Tendency to ripen unevenly. |
| 9 | 9/18 | 23.1 | 66° | 80-86 | 9/22 | 4 | Full sized. Not wilted. More or less dry and insipid. Flesh granular. Good waxy appearance. Aromatic. About 60 percent core rot. No scald. Tendency to ripen unevenly. |

As already indicated, temperature of the fruit may affect the pressure test. The variation between day and night temperatures may be sufficient to make a difference in resistance of 2 to 3 pounds. This difficulty can be eliminated for practical purposes by picking the fruit for testing early in the morning. So far as possible only turgid specimens should be used in making the test. After picking, the fruit should be kept in a closed container or should be covered over with a moist cloth until the test can be made. Allowance must be made for lessened turgidity during periods of drought. It was found that specimens from the larger branches on the inside of the tree are usually more turgid than those from the outer portions. Specimens which are blemished, wormy, or over-colored should be eliminated. After a goodly portion of the crop has been removed, the theoretical rather than the actual resistance, as already explained, should be used as the index of maturity.

If these factors are taken into account, the pressure test should be even more reliable than it has been in the past and many of the irregularities formerly encountered will be alleviated.

## NUMBER OF PICKINGS IN RELATION TO SIZE AND TONNAGE

It is a rather common belief among growers of pears that the size of the fruit and the total tonnage are influenced more or less by the number of pickings made. Even in cases where pears are sold to canneries some growers prefer to dispose of their crop in two or three pickings, thinking that this practice results in better size and consequently in greater tonnage. Preliminary observations during previous tests, however, had indicated that this factor is of less importance than is commonly supposed.

The data obtained in 1923 on this phase of the subject were furnished by twelve Bartlett trees of bearing age in the Oaco orchard at Monroe. Care was taken to select, so far as possible, trees of equal size, vigor, and amount of crop. The trees selected were divided into two lots of six trees each. The crop from the trees of Lot 1 was disposed of in three separate pickings, one-third of the crop being removed on August 15, one-third on August 24 and the remainder on September 14. The crop from the trees of Lot 2 was gathered in a single picking on August 24. The fruit from each picking was counted and weighed, and measurements of the transverse diameter of each specimen were made. Table XIX gives the data appertaining to both size and tonnage.

TABLE XIX. NUMBER OF PICKINGS IN RELATION TO SIZE AND TONNAGE IN BARTLETT PEARS

| Lot No. | No. of trees | No. of pickings | No. of specimens | Total weight of specimens | Average weight of specimens | Percentage of specimens between 2⅜ and 2¾ inches in diameter |
|---|---|---|---|---|---|---|
| | | | | *lbs.* | *lbs.* | % |
| 1 | 6 | 3 | 3301 | 1210.3 | .366 | 84.2 |
| 2 | 6 | 1 | 3885 | 1374.0 | .353 | 65.7 |

From this test it appears that the number of pickings has but little bearing upon total tonnage. This is indicated by the fact that the average weight of the specimens is practically the same whether the crop be disposed of in one or three pickings. There is indication, however, that when several pickings are made, a better distribution of size is obtained. As Table XIX shows, 84 percent of the specimens of Lot 1 are between 2⅜ and 2¾ inches in diameter, while in Lot 2, but 65.7 percent came within these dimensions. It would appear, then, that the disposal of the crop in more than one picking is justified only when uniformity of size is of prime importance. When total tonnage regardless of size is the object in view, this practice does not seem warranted, at least so far as this experiment shows.

## UTILIZATION OF NIGHT TEMPERATURES

Cool night temperatures are characteristic of the climate in the fruit sections of the Pacific Northwest. This is true not only during the fall, but also during the summer months. It is not uncommon for the temperature in the orchard to vary 50° F. between night and day. Cool night temperatures are an asset to the fruit grower if he would only utilize them. Fruit harvested during the hot part of the day will give up much of its heat if left out in the orchard where air circulation is abundant. Bartlett pears at Corvallis registered a temperature of 104° F. when gathered in the middle of the afternoon on August 20, but when left under the trees during the night their temperature went down to 63° F., a reduction of 41.° Had these pears been stacked together in piles in a warm packing shed or warehouse, most of the heat would have been retained. It is safe to say that half the cost and burden of precooling can be eliminated by proper utilization of night temperatures at harvest time.

## RED COLOR AS AN INDICATOR OF KEEPING QUALITY

Some fruit districts in Oregon are noted for the amount of blush or red color which develops on pears. This is especially true in the case of Bartlett and Comice. Experiments show that such pears hold up considerably better than those which are uncolored. Invariably these are firmer in texture and show less wilting and "leathering." They require somewhat longer to reach prime condition and remain firm for a longer time after ripening. They are especially desirable for long distance shipment, and growers who habitually produce such pears might profit by capitalizing this advantage.

## CORE ROT OF PEARS

Core rot, evidently, is a physiological disease, occasionally found in apples and frequently in pears. It is primarily a storage trouble although not infrequently core-rotted fruit is present on the trees. It is characterized by breakdown of the core area and surrounding portion of the fleshy torus. A foul odor is generally present in the advanced stages. In most cases, the fruit is sound to outward appearance. The disease usually makes most progress as the fruit approaches prime eating condition. All varieties of pears seem to be more or less susceptible to core rot, but of the common sorts, Bosc and Comice are most frequently affected.

Though at this time not a great deal is known concerning the nature of core rot, the trouble appears to be associated with over-maturity. Of the various lots of pears under observation during these tests it was only in the cases of late picked fruit that core rot developed to any extent. The various lots of Bartlett picked between August 18 and September 11 showed no evidence of the disease, but those picked on September 14 developed 5 percent core rot and those picked on September 18, only three days later, developed over 60 percent core rot. Comice picked between September 17 and October 10 showed no core rot in storage. Comice pears picked on October 13, on the other hand, developed 31 percent core rot, while those picked on October 19, developed 100 percent core rot.

Drain, 1923, found that specimens of Le Conte, Anjou, and Bosc core-rotted less after the calyx ends had been sealed with melted paraffin.[9] This is in keeping with the idea that core rot is linked with over-maturity, since the author found that the use of paraffin wax in the basin tends to retard the life activities of the fruit.

## EXPERIMENTAL—PART II. APPLES

### THE PRESSURE TEST AS APPLIED TO THE APPLE

The pressure test as an indicator of picking maturity in the apple has met with varying success. Murneek, 1921, found that in general apples show a gradual decrease in resistance to pressure prior to the time of harvesting.[4] Burroughs, 1922, found a total decrease in resistance in Wagener of only three-fourths of a pound during a period of three weeks and infers that so far as this variety is concerned the test is not sufficiently indicative to be of value as a guide to time of picking. Magness and Diehl, 1924, on the other hand, observed a rather rapid decrease in resistance at the close of the growing period in Winesap, Rome, Ben Davis, and Delicious.[2]

Table XX gives the results of the pressure test determinations made in 1923 on Grimes, Jonathan, and Ortley. These tests were rather comprehensive and the data from them may be taken as representative of the general conditions existing throughout the harvest season. Determinations were made upon both pared and unpared surfaces, but since only a constant difference appeared between the two sets of readings, only the results obtained with the unpared fruit are given.

TABLE XX. DECREASE IN THE RESISTANCE TO PRESSURE IN APPLES AS INDICATED BY THE PRESSURE TESTER

| Dates | 9/17 | 9/26 | 10/2 | 10/8 | 10/13 | 10/20 |
|---|---|---|---|---|---|---|
| **Grimes, 1923—Willamette Valley.** | | | | | | |
| Pressure test | 28.0 | 25.0 | 24.2 | 23.2 | 24.8 | 24.2 |
| **Jonathan, 1923—Willamette Valley.** | | | | | | |
| Pressure test | 21.6 | 20.2 | 19.1 | 19.7 | 18.8 | 18.5 |
| **Ortley, 1923—Willamette Valley.** | | | | | | |
| Pressure test | ...... | 23.9 | 23.9 | 22.5 | 23.3 | 22.7 |

Although a gradual decrease in resistance took place during the season, it is apparent that this is not sufficiently indicative to act as a guide of picking maturity. Grimes, for example, shows a total decrease of only 3.8 pounds in 33 days. Jonathan for the same period shows a decrease of only 3.1 pounds in spite of the fact that during this time this variety passed from a stage of immaturity to one far beyond the optimum condition for picking. Ortley shows a decrease in resistance of only 1.2 pounds in 22 days.

There are several factors that tend to render the pressure test inefficient as an indicator of picking maturity in apples. First, cultural conditions are known to produce wide differences in the texture of the fruit. Second, differences in resistance occasioned by color intensity are more pronounced in apples than in pears. Third, the proper harvest season of many varieties of apples is considerably shorter than that of pears in general. And fourth, as already indicated, the amount of decrease in resistance throughout the season is too small to make the test indicative. Most of the softening that occurs in apples takes place following the proper time of picking.

As an indicator of the condition of apples after harvest, however, the pressure test gives considerable promise. Experimental work thus far conducted shows that the degree of maturity of apples in storage can be ascertained rather accurately by means of the pressure tester.[6]

## TIME OF PICKING IN RELATION TO SIZE

Six separate pickings of Grimes were made during the picking season of 1923. The fruit in each case was picked from six trees which had been set aside for this test. Size was determined by weighing the specimens and measuring their transverse diameters. Lots from each picking were placed in storage. Table XXI gives the figures obtained at the time of picking.

TABLE XXI. TIME OF PICKING IN RELATION TO INCREASE IN SIZE IN GRIMES APPLES

| Lot No. | Date | Pressure test | Average transverse diameter | Average weight of specimens | Percent increase in weight |
|---|---|---|---|---|---|
| | | *lbs.* | *in.* | *lbs.* | % |
| 1 | 9/17 | 28.0 | 2.75 | .35 | ...... |
| 2 | 9/26 | 25.0 | 2.83 | .40 | 14.3 |
| 3 | 10/2 | 24.2 | 2.92 | .42 | 20.0 |
| 4 | 10/8 | 23.9 | 2.95 | .44 | 25.7 |
| 5 | 10/13 | 24.8 | 3.01 | .45 | 28.8 |
| 6 | 10/20 | 24.2 | 3.13 | .46 | 31.4 |

Obviously, Grimes in this case shows a considerable increase in size from time to time during the harvest season. The storage tests from this fruit indicate that nothing was lost in either eating or keeping quality by leaving the fruit longer on the trees. In fact, the fruit from the later pickings, aside from being much larger in size, showed less wilt and developed more of the characteristic Grimes flavor. This observation is corroborated by recent work at the Iowa Experiment Station.[11]

In 1923, the bulk of the Grimes crop in the Willamette Valley was gathered between September 10 and 18. So far as the above test indicates, picking at this time resulted in a considerable loss of tonnage and a sacrifice of quality. The Grimes apple in the Willamette Valley clings to the trees remarkably well during the season of maturity, and the loss from wind has been a negligible factor in recent years.

## TIME OF PICKING IN RELATION TO KEEPING QUALITY

Table XXII gives the results obtained with six separate pickings of Jonathan made during the season and stored under identical conditions. These pickings cover a period of 33 days. At the time of the first picking the fruit was still somewhat undersized and considerably undercolored for the variety, while at the time of the last picking the fruit was full sized and highly colored. Three examinations of the fruit were made during the storage period, the fruit being listed as "unmarketable" when it showed unmistakable evidence of internal breakdown.

TABLE XXII. TIME OF PICKING IN RELATION TO KEEPING QUALITY OF JONATHAN APPLES

| Lot No. | Date of picking and storing | Pressure test | Condition at time of picking | Temperature of storage room (Fahr.) | Relative humidity of storage room | Percent unmarketable Nov. 7 | Percent unmarketable Nov. 17 | Percent unmarketable Jan. 3 |
|---|---|---|---|---|---|---|---|---|
| | | *lbs.* | | | | % | % | % |
| 1 | 9/17 | 21.0 | Somewhat undersized, undercolored | 66° | 80-86 | 0.0 | 4.1 | 5.0 |
| 2 | 9/26 | 20.2 | Somewhat undersized, undercolored | 66° | 80-86 | 4.3 | 4.3 | 8.8 |
| 3 | 10/2 | 19.1 | Full sized, medium color | 66° | 80-86 | 5.2 | 5.2 | 25.0 |
| 4 | 10/8 | 19.7 | Full sized, good color | 66° | 80-86 | 8.3 | 8.3 | 24.0 |
| 5 | 10/13 | 18.8 | Full sized, good color | 66° | 80-86 | 18.1 | 21.7 | 45.9 |
| 6 | 10/20 | 18.5 | Full sized, high color | 66° | 80-86 | 41.6 | 70.8 | 79.2 |

Time of picking, obviously, had considerable effect upon the amount of internal breakdown which occurred. Internal breakdown in storage is a factor of considerable importance in Willamette Valley Jonathans during some years, and there is little doubt that this trouble is essentially a matter of overmaturity. In order to attain high color growers are inclined to leave Jonathan on the trees far beyond the time of its proper picking maturity. Internal breakdown in Jonathan seems to be associated, also, with the type of the apple. The smaller, oblong, and brightly colored specimens usually show much less breakdown than those which are larger, more blocky in type, and of dull brown color.

Experiments show, further, that much less Jonathan Spot develops on fruit of the early pickings. Jonathan apples picked on September 24 developed 36.5 percent spot, while those picked on October 10 showed 78.1 percent spot at the close of the storage period.

## BLOOM IN RELATION TO LOSS OF WEIGHT AND KEEPING QUALITY

The epidermis of the apple and other fruits is naturally covered with small wax particles which give the characteristic whitish or bluish tinge known as the "bloom." The true function of the bloom is not definitely known, save that it affords protection and seems to be associated with certain of the life processes. With the modern practices of handling apples, a great deal of the bloom is usually lost. The action of the fingers and the use of canvas bags and other utensils by the pickers result in a considerable loss of bloom. In many cases the sorters wear cotton gloves and practically polish the apples before they are packed. This is especially true since in certain quarters the trade objects to the presence of spray material on the fruit. Growers and dealers are naturally interested in whatever effect removal of the bloom may have upon the subsequent keeping quality. The following experiment gave some interesting data relative to loss of bloom.

Specimens of Rome were gathered on October 11, and divided into two lots of equal number. Care was taken to select apples of the same degree of maturity and color intensity so far as possible. The fruit appeared to be fully matured at this time. The specimens of Lot 1 were polished; i.e., the bloom was removed by rubbing with a piece of cloth. Lot 2 was left unpolished. Weighings of the two lots were made and the specimens were placed in storage under identical conditions, the temperature being 66° F. and the relative humidity 52 to 56 percent. Other weighings and observations were made on November 5, March 20, December 12, and January 2. Table XXIII gives the data relative to loss of weight by the specimens of both lots.

TABLE XXIII. BLOOM IN RELATION TO LOSS OF WEIGHT IN ROME APPLES

| Date | Weight | Loss of weight | Loss of weight in percents |
|---|---|---|---|
| | *grams* | *grams* | % |
| Polished. | | | |
| October 11 | 2106.90 | ........ | ...... |
| November 5 | 1956.10 | 150.80 | 7.1 |
| November 20 | 1888.15 | 218.75 | 10.3 |
| December 12 | 1788.50 | 318.60 | 15.1 |
| January 2 | 1701.50 | 405.40 | 19.2 |
| Unpolished. | | | |
| October 11 | 2432.00 | ........ | |
| November 5 | 2324.30 | 107.70 | 4.4 |
| November 20 | 2274.10 | 157.90 | 6.5 |
| December 12 | 2208.50 | 223.50 | 9.2 |
| January 2 | 2148.90 | 283.10 | 11.6 |

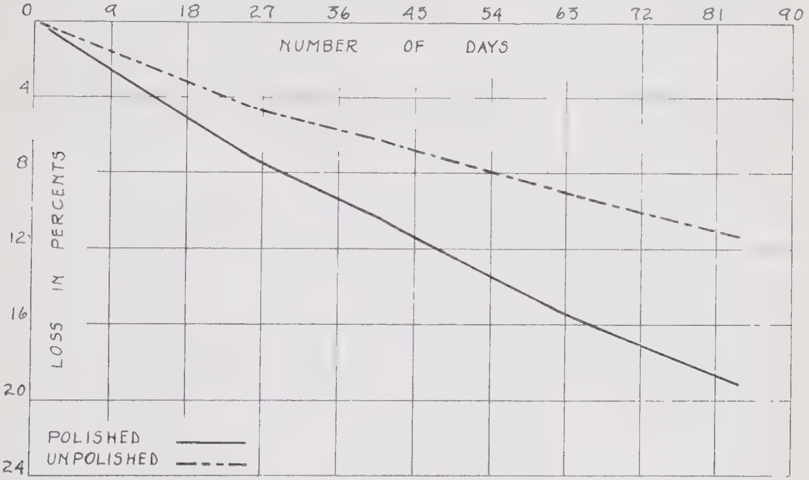

Fig. 2. The relation of bloom to loss of weight in apples.

Certain rather significant conclusions seem apparent from this experiment. Not only does the polished fruit show a greater total loss of weight, but it shows, also, a uniformly greater rate of loss of weight for the period (Fig. 2). The difference in loss of weight, in other words, is constant throughout the season, and there is no indication that the heavy loss by polished fruit early in the period will eventually be equalized by the loss of the unpolished specimens.

In the course of this test it was obvious that the polished fruit was going down more rapidly than the other. By December 12, the unpolished apples had so wilted that they were practically unmarketable. The unpolished apples at this time showed some evidence of wilt but were still marketable. On January 2, thirty-four percent of the polished lot showed internal breakdown. The fruit from the unpolished lot, on the other hand, was all sound at this time, although it showed considerable wilt.

## SUMMARY

1. Loss of weight after harvest may be a considerable factor in the handling of pears. Excessive loss of weight not only results in decreased tonnage but causes wilting which seriously impairs the appearance of the fruit. Wilted pears are usually dull and unattractive and do not become aromatic. A loss of 3 to 4 percent is usually sufficient to cause noticeable wilt.

2. Though several factors may contribute to loss of weight in pears insufficient humidity appears to be its chief causal agent. Storing at a relative humidity of 80 to 85 percent practically prevents loss of weight in all cases.

3. Time of picking apparently has bearing upon loss of weight. Bartlett pears picked on August 14 lost 9.7 percent of their weight during 264 hours of storage, while those picked on September 14 lost only 5.8 percent of their weight during this time.

4. The use of common fruit wraps and commercial oiled papers does not seem to be effective in preventing loss of weight in pears.

5. The rate of loss of weight in pears seems to be constant throughout the storage period.

6. Apparently every loss of weight is accompanied by a corresponding loss in volume.

7. Pears from heavily loaded trees are usually more advanced in maturity than those from lightly loaded trees in the same orchard. As indicated by the pressure tester the time of picking pears on heavily loaded trees may be from 8 to 12 days earlier than that of pears on lightly loaded trees.

8. The pressure tester may be materially influenced by several factors, chief among which are (1) temperature of the fruit, (2) turgidity, (3) removal of a portion of the crop, (4) amount of russeting, and (5) intensity of the "over" color.

9. Such general indicators of maturity as (1) ripening of imperfect specimens, (2) changes of the "ground" color, and (3) loss of bloom were found to be valuable in determining time of picking in pears. Such factors as (1) ease of separation from the spur, (2) color of the seeds, and (3) size of the fruit were found to be unreliable as indicators of maturity.

10. Time of picking has considerable bearing upon the time required for pears to reach prime condition. When held at 66° F., Anjous of the first picking required 54 days to ripen, while those of the last picking were ready for eating in 26 days. This seems to be true of all varieties.

11. Anjou seems to have a rather long picking season. All fruit of this variety harvested between September 4 and 28 developed good quality. The average decrease in resistance for the season was 0.4 pound per day. Apparently it is safe to pick Anjou when the pressure tester registers between 24 and 19 pounds. When picked prematurely this variety wilts badly in storage, becomes dull in appearance, and remains more or less astringent. When picked too late, it lacks considerably in juiciness.

12. Comice, unlike Anjou, seems to have a fairly short picking season. Real Comice quality was developed only by the fruit gathered between October 1 and 9. The average decrease in resistance for the season was 0.3 pound per day. Seemingly this variety should be picked when the pressure tester registers between 20 and 18 pounds. When picked too green Comice wilts badly in storage and develops only inferior quality. When picked too late it lacks in juiciness and goes down rapidly, due chiefly to rotting at the core.

13. Winter Nelis gathered between October 1 and 20 developed good quality. This variety appears to be ready for picking when the pressure tester registers between 33 and 29 pounds on clear skinned specimens. Winter Nelis pears of the very early pickings wilted more or less, lacked in sweetness, and were undersized. Those picked very late in the season lacked in juiciness.

14. The results obtained with Bartlett corroborate rather closely those of the previous investigations. Pears suitable for one purpose or another were harvested between August 20 and September 14. The entire crop, however, should be disposed of when the pressure tester registers between 35 and 25 pounds.

15. Total tonnage does not seem to be materially affected by the number of pickings made. When the crop is disposed of in several pickings, however, a better distribution of sizes is obtained.

16. Cool night temperatures may be utilized to advantage in the handling of pears. The temperature of Bartlett specimens picked during the warm part of the day dropped from 104° F. to 63° F. when left outdoors during the night.

17. Pears with a red cheek or blush hold up best during long distance shipment.

18. Core rot in pears seems to be associated with overmaturity. No evidence of this trouble was noted in Bartlett and Comice except in the lots that were picked comparatively late in the season.

19. Apples, in the main, show a decrease in resistance prior to the time of picking. In most cases, however, the decrease is not sufficiently indicative to be a reliable guide to time of picking.

20. Grimes shows a material increase in size toward the end of the growth period. From September 17 to October 20, an increase in size of 31.4 percent was noted in this variety. Indications are that Grimes is commonly picked prematurely in the Willamette Valley.

21. Time of picking seemingly has bearing upon the development of internal breakdown in Jonathan. Fruit of this variety gathered on September 17 developed only 5 percent breakdown during the storage period, while that picked on October 20 became affected to the extent of

79 percent. It is apparent that growers commonly sacrifice keeping and dessert quality in this variety in order to obtain high color.

22. Loss of "bloom" seemingly increases the rate at which apples lose weight in storage and shortens the life of the fruit.

## ACKNOWLEDGMENTS

The author wishes to express his appreciation to Professor W. S. Brown and Dr. E. M. Harvey for valuable suggestions and to Mr. B. W. Johnson and Dean G. A. Covell for their cooperation in carrying on these experiments.

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Oregon Agricultural College

Experiment Station

# The European Earwig

By

B. B. Fulton

CORVALLIS, OREGON

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## SUMMARY

The European earwig has been present in Oregon since 1909 but did not attract much attention until several years later. It is a pest chiefly on account of its disagreeable habit of concealing itself in or about houses. It is also destructive to garden vegetables and flowers, and is occasionally a pest of bush and tree fruits.

The best method of control is by means of a poison bran bait scattered about in the evening. Sodium fluoride is recommended as the best poison, from the standpoint of both effectiveness and economy. For bait to be scattered over the ground clear wheat bran is recommended; for bait to be applied to trees, buildings, and other objects, ground oat hulls are recommended.

It is essential that all property in the same neighborhood be treated on the same evening. For this reason control work is most effective when carried on as an organized community effort.

No effective parasitic or predatory enemies of the earwig have yet been found in Oregon. An effort will be made to introduce parasites from Europe.

The European earwig lives over winter in the ground in small cavities a few inches beneath the surface. The eggs are laid in the cavity during the fall or early in spring, usually forty to sixty in number. The female guards and cares for the eggs and for the young earwigs until they leave the nest. Hatching takes place in April sometime between the blossoming periods of the cherry and apple. The young earwigs remain in the nest until after the first moult. Later they wander away from the nest and in the later stages are strongly inclined to climb up on objects of any kind during the night. After the young earwigs leave the nest the female continues to feed for a period and then goes into the ground to deposit a second lot of eggs.

If control measures are applied when the majority of young earwigs begin to feed at night it is believed that this brood and the adults can be poisoned before the second lot of eggs is deposited. The young of the second brood do not appear above ground until the first brood is nearly or quite matured.

There are four nymphal instars, which can be distinguished by differences in the thorax, forceps, and the number of antennal segments.

# The European Earwig

By

B. B. Fulton

The earwig has been recognized as a distinct form of insect life since the middle ages. The name is descended from the Anglo-Saxon word *earwicga* which literally meant "ear creature." It is an interesting fact that in nearly all European languages the popular name given to this insect has similar significance.* In German, Dutch, Swedish, Spanish, and Italian the earwig is known literally as an ear worm. The Germans also call it an "ear-borer," the Danish "ear-twister," and the French and Portugese a "pierce-ear." All of these names refer to a widespread superstition that earwigs crawl into the ears of sleeping persons. Since this idea is not known to be substantiated by fact, it seems improbable that it could have arisen independently among so many different peoples. This suggests the possible antiquity of its origin.

By far the best known species of earwig, the one which is largely responsible for popular recognition of its kind, is the common European earwig, *Forficula auricularia* Linné. It has gained fame by making itself obnoxious.

Some four hundred other species have been described but the majority of them inhabit warm or tropical countries. Most of them are inconspicuous in appearance and live by day in concealed situations and so are seldom noticed. Fifteen species of earwigs are known to inhabit the United States. Several of them are introduced forms. Seven species have been found in the Northern states; five have been taken in the Pacific Coast states and only two are known in Oregon. These are the European earwig and the Little earwig, *Labia minor* (Linné), which can be distinguished from each other by the great difference in size; the length of the former is $\frac{5}{8}$ to $\frac{3}{4}$ of an inch while the latter measures only about $\frac{1}{4}$ of an inch.

Except for a few species, little is known of the life of earwigs. They have been found under stones or bark or under litter on the ground. The maritime earwig, *Anisolaba maritima* (Géné) is partial to the decaying drift of sea beaches. The little earwig, *Labia minor* (Linné), is commonly found in manure piles. A species of the Southwest lives in dead giant cactus; two species have been found among the filth of slaughter houses; three species are known to live among the rank growth of grass and vegetation in low places.

The earwigs form a distinct group of insects which are characterized by their wings and their forceps. They were formerly classified as close relatives of the grasshoppers, crickets, and roaches but are now usually considered as a distinct order under the name "Dermaptera." The fore wings are represented by small leathery wing covers which meet at the median line and resemble abbreviated elytra of a beetle. The hind wings are large and when at rest are folded both radially and

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*In the Century Dictionary and Cyclopedia the following names are given for various languages. Dutch, *oorworm;* German, *ohrwurm,* and *ohrbohrer;* Swedish, *ormask;* Danish, *orentvist;* French, *perce-oreille;* Portugese; *fura-orelhas;* Spanish, *Gusano del oido;* Italian, *verme auricolare.*

transversely and lie mostly concealed under the wing covers. Some of the species of earwigs are devoid of wings, and those which have them are seldom seen flying.

All earwigs have a pair of forceps or "pinchers" at the hind end of the body, an organ found only in one other group of insects, the genus *Japyx* of the Thysanura, which are small primitive insects in no way resembling earwigs. The forceps of the males are of different form and more highly developed than those of the females, and in some exotic species they attain remarkable size and peculiar form.

## DISTRIBUTION

Like the cockroaches, a number of species of earwigs have followed the trade routes of man and have become nearly world-wide in their distribution. The European earwig is rapidly extending its range and may soon be known as a cosmopolitan species. Its native home includes the greater part of the continent of Europe, and at present this insect has outposts in North America, South America, New Zealand, and Tasmania. The South American record is assumed from the fact that a shipment of fertilizer from Buenos Aires and Santos was thoroughly infested with European earwig. The first extensive outbreak in North America, was at Newport, R. I., where earwigs attracted attention in 1911; since then they have multiplied and become a pest over a considerable area. Records show that the earwig has been present in Oregon since 1909. A specimen which was identified as an earwig was sent to this Experiment Station in 1910 from Albany, Oregon, accompanied by a letter in which the writer claimed that the insect had been a pest during the previous summer also. Little more was heard of the earwig until 1915, when it attracted much attention in Seattle, Washington, by its numbers and disagreeable habits. Afterwards, letters from both Portland and Albany, Oregon, began to call attention to the pest. By 1919, it had become established in Vancouver and New Westminster in British Columbia. In 1923, the earwig was known to occur in the following additional localities: Astoria, Salem, Eugene, Corvallis, Forest Grove, Gresham, Roseburg, Dayton, Mill City, Colton, and Blodgett, in Oregon; Vancouver, Camas, and Anacortes, in Washington; and Berkeley, in California. We also had unconfirmed reports of its occurrence in Edmonds and Everett, Washington.

## MEANS OF DISPERSION

It is impossible to say how the original ancestors of the earwig in the various infested areas were imported into America. We know that earwigs have been intercepted from time to time on nursery trees and bulbs from Europe and this seems the most plausible explanation of their entrance into this country. Their spread from place to place is a simple matter, due to their habit of concealment in any object which offers a narrow, dark hiding place. When such objects are transported from an infested district, there is always danger that some earwigs will be carried away also. We received a specimen of earwig from Ontario, Oregon, found in a package of daily papers arriving from Portland after a journey of over four hundred miles. Flowers are common hiding places for earwigs, especially those with many petals such as roses.

Such flowers should never be removed from an infested area without being thoroughly inspected.

The main earwig-infested area in Portland, which covered a few city blocks in 1915, spread until it included an area in 1923 estimated at eight hundred blocks. How much of this spread has been due to the natural migrations of the insects has not been determined, but we believe that city streets serve to some extent as barriers and that without human aid in transporting the earwigs their dispersion from block to block would be slow. The fact that the infestation at the border of the main area is patchy and disconnected is evidence that the insects are disseminated largely by human agency.

## DISAGREEABLE HABITS

At the present stage of infestation, confined mostly to cities, earwigs are a pest chiefly on account of their disagreeable habit of concealing themselves in or about houses. At night they swarm over porches in such numbers that many people prefer to remain inside on a summer evening rather than spend it with such unwelcome guests.

In the morning earwigs are found by the handful under rugs and cushions which have been left outside. They crawl into basements and hide in the laundry which is waiting to be ironed. In the bedrooms they sometimes find their way into the clothing hanging in closets. A man reported that he pulled on a sock one morning which contained three earwigs. A correspondent in a letter appealing for information describes the situation as follows: "Literally thousands and thousands of these bugs inhabited my premises last summer. They made it almost impossible to live in my home; they inhabited the sleeping porch till we had to leave it. They work mostly at night but in daytime might be found in kitchen drawers and often burrow an inch into a loaf of bread. They crawl over ceilings at night and drop on the bed, or inhabit themselves in a person's clothing during the night, and while their bite has never proved serious it is entirely uncomfortable." No part of the house seems to be entirely free from earwigs, not even the roof, and it is almost impossible to keep them out by the use of screens. The pests have become so annoying in some districts that property values have depreciated considerably.

As disseminators of filth and disease the earwig probably stands about in the same class with the cockroach. The body of the cockroach is known to teem with bacteria inside and out, and in its nightly foraging expedition it scatters these germs in its path. The habits of earwigs are such that we would expect them to be equally effective as carriers of disease. They are prone to crawl about over sidewalks, where if anywhere the germs of human diseases should be found, and later they may find their way into the house and nibble our food.

## FOOD

The European earwig is one of the most omnivorous of insects, and will eat almost anything that can be considered edible. Their normal diet consists mainly of green plants, but they will pass by leaves and flowers for any occasional morsel of a more nourishing quality that they may happen to find. Sugar, starch, vegetable oils, fat or lean meat, are all eagerly devoured. They eat dead insects and such live ones as they are able to capture and overpower. Littler[20] says that in Tasmania the European earwig destroys codling-moth larvae under tree bands. Brindley[7] gives a large number of references to European literature in which the earwig is recorded as feeding on various caterpillars, pupae, and scale insects. The author has fed living blow-fly maggots to both adults and nymphs. The nymphs in this case were in the second instar and no larger than the maggot, but several of them took hold of the victim at once and within ten minutes there was nothing left. Earwigs do not hesitate to eat each other when confined without food, but it is not known whether they kill weakened individuals or wait until they die. They devour the dead of their own kind even out of doors, but cannibalism would not be likely to occur where there is an abundance of food. There was a rather high mortality among the families reared in the Station laboratory, but here the conditions of food and moisture were not always ideal.

The plant food of the earwig includes a long list of garden vegetables, flowers, fruits, and wild plants. They exhibit certain preferences. The kind of plants attacked depends to some extent on what is available. If a favorite food is not at hand they will select the next best, and one cannot say positively that any plant is safe from earwig attack. Among the common plants which to the author's knowledge are subject to severe injury to the foliage are bean, potato, beet, cabbage, cauliflower, pea, dahlia, zinnia, sweet-william, and fig. A great many flowers are more or less injured by earwigs feeding on the petals and stamens. Dandelion flowers are a favorite food for the young nymphs. Earwigs eat numerous holes in the leaves of orchard trees and berry bushes, but the author has never seen any of these plants seriously defoliated. Strawberries have been observed with a cavity in the heart full of half-grown earwigs, and the adults are said to tunnel into ripe apples, prunes, and peaches. Brindley[8] gives a list of seventy-four species of plants including most of the common garden vegetables, flowers, fruits, and weeds on which caged earwigs fed on some part of the plant. In reviewing economic literature we find that in Europe earwigs have caused serious injury to the following crops: in Denmark, cauliflower (completely destroyed), beets, clover, dahlias; in Sweden, barley, wheat, cabbage, ornamental plants; in Norway, cabbage and other vegetables; in England, hops; in Austria, vegetables; in Russia, beets, potatoes, chrysanthemum stems; in Switzerland, pear foliage. Apparently the original home of the earwig is in no sense free from its depredations.

## CHARACTER OF INJURY

The typical injury by earwigs appears as numerous small irregular holes in the leaves (Fig. 1). Tender foliage such as dahlia leaves are often completely devoured except the midrib and a few large veins. In the case of many other plants the smaller veins are left and the leaf is finally skeletonized. The work often appears like that of garden slugs, but the absence of any trace of slime on the leaves will serve to distinguish it. Earwigs will usually be found hiding in the ground near plants injured by them.

## CONTROL MEASURES

**Trapping.** The oldest control method and the one commonly used in Europe is trapping. A flower-pot half full of excelsior is inverted over a short stake in the ground. Earwigs hide in the excelsior, which is removed and shaken over hot water or water with a film of oil on top. Burlap sacks or pieces of old garden hose about a foot long also make good traps. Traps should be placed among plants, near buildings or fences, or in tree crotches. Literally thousands of earwigs can be killed in this way during the course of a summer, and the trapper may gain considerable mental satisfaction from his labors, but unless some other control measures are used he will still have plenty of earwigs.

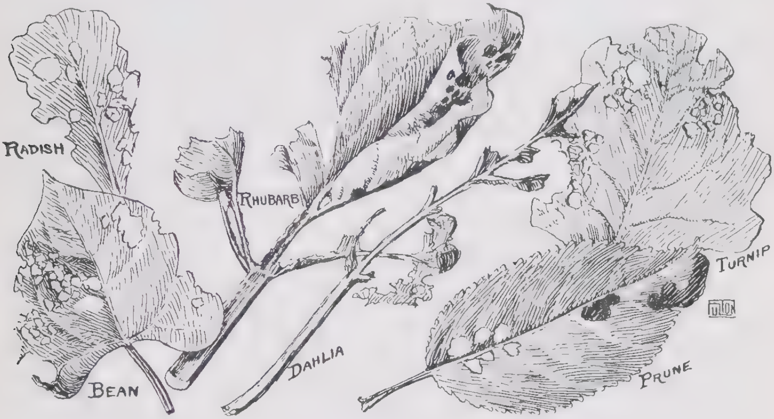

Fig. 1. Specimens of typical injury to foliage by earwigs.

**Poison baits.** During the summers of 1921 and 1922, the writer experimented with various poisons and attractants. The materials were placed at night in traps which the earwigs could enter but not leave and each morning the insects were removed and caged and a daily mortality record kept. The results of these experiments, which were published in a technical paper,[17] can be summarized as follows:

1. Wheat bran sweetened with molasses is sufficiently attractive to earwigs for all practical purposes, and clear wheat bran free from shorts is superior to all other substances tried for scattering over the ground.

2. Ground oat hulls are slightly more attractive than wheat bran. The fibrous quality of the former makes this material especially desirable for a bait to be applied to objects as a poison for climbing earwigs. Rice bran could also be used for this purpose but not for scattering on the ground.

3. The addition of amyl acetate (banana oil), anise oil, or meat extract does not materially increase the attractiveness.

4. Glycerin does not lessen the attractiveness of a bait and increases the length of time during which the bait is attractive.

5. When used in a poison bait for European earwig, in equal proportions by weight, sodium fluoride has an equal or greater amount of toxicity than arsenious oxide (white arsenic) and acts more rapidly. Sodium fluoride is slightly more toxic than sodium arsenate. Calcium fluoride is only slightly toxic.

Sodium fluoride has certain other advantages which make it more desirable as a poison for earwig bait than white arsenic or paris green, substances which are commonly used in poison baits for insects. (1) At present the cost is less than for the arsenicals. (2) It is soluble in water and thus easier to incorporate in a poison bait than either white arsenic or paris green. (3) It is less toxic to humans than arsenicals. According to H. B. Baldwin* sodium fluoride has been accidentally taken in doses of five, six, and nine grams without causing death, although severe sickness resulted. The same author took .03 gram without any noticeable effect, but .25 gram in two minutes produced nausea which lasted several hours. The last amount would be contained in about a tablespoonful of mixed bait. According to the above figures an adult person might eat as much as a quarter pound of the mixed bait without causing death, since at the recommended strength it would contain only about three grams of sodium fluoride. In the case of arsenious oxide much less than a gram is said to cause death.

## RECOMMENDATIONS FOR CONTROL

Poison bran bait should be scattered over the ground in the evening just before dark. This should be done on warm nights after most of the young earwigs are old enough to feed above ground or when most of them are in the second instar or older. In Portland the best time to begin poisoning usually comes sometime in May. One year the young earwigs did not come out in large numbers until after June first. An unusually early season might bring them out by the last of April. This point can be determined only by observation.

The poison bran should be scattered over every foot of ground. By throwing it hard with a wide swing of the arm it can be scattered more evenly and quickly than by simply dropping it or shaking it through the fingers. On open lawns a very thin scattering is sufficient. More material should be applied along walks, curbs, fences, walls and buildings and around trees, bushes and thick vegetation (Fig. 2). The work should be done during clear weather and the grounds should not be watered for a few days, for this washes out the poison.

### FORMULA FOR POISON BRAN

| | |
|---|---|
| Sodium fluoride | 1 pound |
| Molasses | 2 quarts |
| Water | 2 gallons |
| Wheat bran | 16 pounds |

Dissolve the sodium fluoride and then the molasses in the water. Stir well and add this solution to the desired amount of bran to be used and mix thoroughly. The bran should be wet but not enough to make it ball up nor wet enough to drip without being pressed. Only clear wheat bran free of shorts is advised, and the above formula is based on this material. If mill-run is used great care must be employed not to leave large lumps on the ground. The amount of molasses in the above formula is given in a convenient amount for a small batch of poison bait. For large scale production see formula on page 13.

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*Baldwin, H. B. The toxic action of sodium fluoride. Journal American Chem. Soc. 21, pp. 517-521, 1899.

**Late summer poisoning.** It is well to follow up the general application of poison bran bait by the use of small amounts of poison bait applied to trees, walls, and other objects several times during the summer, to catch the earwigs after they begin to climb at night.

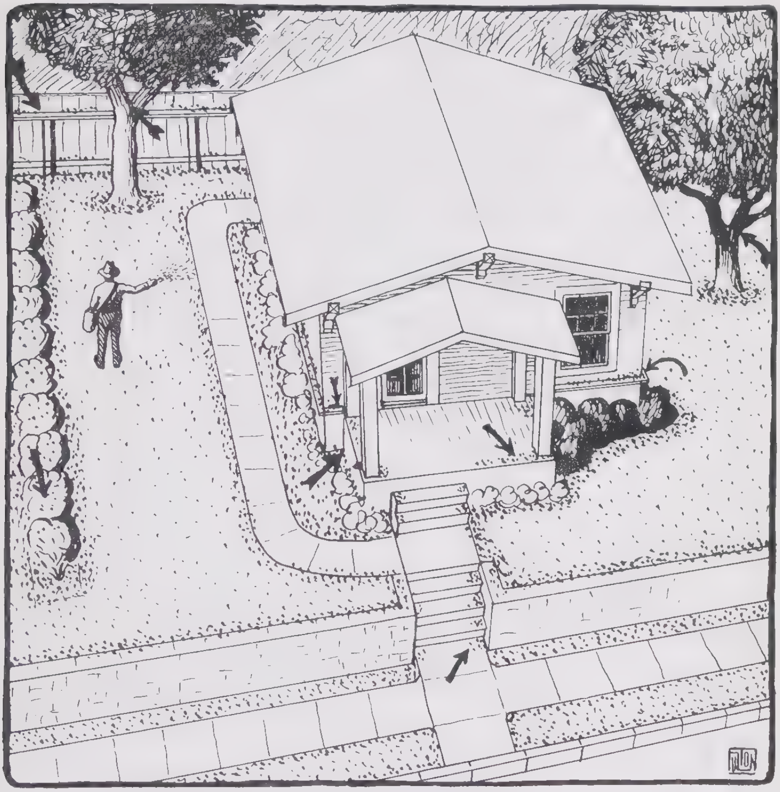

Fig. 2. Diagram showing proper distribution of poison bran bait as indicated by dots.

For this purpose it is well to have a mixture which will not dry for several days. This may be accomplished by substituting glycerin for a third of the amount of liquid used. Oat hulls will make a mixture which will stick to objects better than wheat bran. The following mixture is recommended:

| | |
|---|---|
| Sodium fluoride | 1 ounce |
| Molasses | 5 ounces (⅓ pint) |
| Glycerin | 5 ounces |
| Water | 5 ounces |
| Ground oat hulls, about | 1 pound |

Mix by first dissolving sodium fluoride in the water, add molasses and glycerin, and mix with enough ground oat hulls to make a wet mash. Smear pinches of this in the crotches of all trees or around the trunk; leave pellets of it at intervals of about six feet along all fences and walls, and along the top of the house foundation, in cracks of barns and other buildings, or anywhere that the earwigs are seen crawling.

It is very probable that no dead earwigs will be found on the day after an application of poison bran. In experiments in which the recommended strength of poison was used, none of the earwigs which had fed on the bait were found dead on the first morning, and only about one-third of them were dead on the second morning. It was not until the fourth morning that most of them were dead. Poisons act more rapidly on insects during warm weather. Earwigs which have eaten a very small amount of poison may live as long as a week, but during that time they remain quiet and do not eat.

*Caution.* Sodium fluoride is poisonous to human beings, but death from its use is rare. Wherever small children are present care should be used to prevent them from eating any of the poison bran. It should be scattered so that no large lumps remain on the ground. It is safe to treat poultry yards if the above precautions are taken and not too liberal amounts used. Material applied to trees and other objects should be placed beyond children's reach. A thorough sprinkling of the grounds with water after the bran has been on a couple of nights will wash out the poison. Calcium lactate or other soluble calcium salts may be given as an antidote—dosage 1 gm. (15 grains) or a few spoonfuls of lime water may be substituted. Milk is said to aid in recovery.*

**Cooperative poisoning.** Earwigs crawl about at night and do not respect line fences. It is essential that neighboring property be treated at about the same time, preferably on the same night. If cooperation is possible it is desirable to have everyone in the same block scatter poison on the same evening. Parkings and alleys should not be neglected. Without cooperative action on neighboring property, treated grounds may become thoroughly reinfested during the course of a summer.

**Community earwig poisoning.** The ideal method of controlling earwigs is an organized community-wide campaign, leaving the preparation and application of the poison in the hands of a county agent, horticulturist, or other official competent to carry on the work. He should have full power by law to carry on the work on any property in a district known to be infested, without having to inspect each holding individually. This plan of control eliminates the effect of the minority who may be unwilling to cooperate or of some individual who may have some untested pet remedy which he insists on using. The campaign is valuable also in educating the public in control methods and their possibilities.

**The Portland earwig campaign of 1923.** The administration of an earwig campaign in Portland, 1923, was placed in the hands of the State

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*DeOng, E. R. Jour. Econ. Entomology. Vol. 17, p. 343, 1924. Toxicity of Sodium Fluoride to Man.

Board of Horticulture,* whose powers under the state law made it possible for them to carry on the work wherever necessary without interruption. The various phases of the work included: (1) scouting for earwigs and mapping of infested territory, (2) manufacture of poison baits, (3) transportation of poison bait to territory to be treated, (4) scattering of poison bran bait over the ground, (5) application of adhesive poison bait to tree trunks, fences, buildings, etc.

(1) *Scouting.* The easiest and most rapid method of making a general survey of infested territory is that of setting out non-poisonous, attractive bait along a line of travel and then going back over the same route after a time and examining the baits with a flashlight for the presence of earwigs. Scouts were given small quarter-section maps of the territory to be covered. They would travel only on streets lying in one direction; that is, they would go west a half mile on one street, and east on the next until the whole quarter section had been covered. Bait was dropped in small piles on the grass at the edge of the sidewalks, one near each corner and one at the middle of each block, so that the location could be remembered. This necessitated crossing the street three times for each block traveled and left six deposits of bait on each block. If earwigs were found at any one of the six places the block was considered infested. Each scout kept a record of observations in a note-book which was turned in each day and the results were plotted on a map.

Reports of infestations by individuals in various parts of the city were very helpful in the survey work. They were verified whenever it seemed necessary.

(2) *Mixing poison bait.* A mixing platform for making poison bait was built in a city park within the infested district. The platform was twenty feet square, built of matched flooring, and had a twelve-inch plank as a retaining wall around the edge. There was a large shed beside it for storage of supplies of bran and other properties. An electric light overhead and a water tap with hose near at hand were essential parts of the equipment. Barrels were placed along two sides of the platform for storage of solutions. Other equipment consisted of shovels, rakes, pails, scales for weighing poison, and a long-handled stew-pan for handling molasses.

The barrels for storing the solution held about sixty gallons. They were marked at the forty-five gallon level and filled with water to that point. Twenty pounds of sodium fluoride was dissolved in each and then seven gallons of molasses. This amount of solution would wet to the proper consistency six sacks of bran or 360 pounds. The bran was dumped on the floor and one man poured on the solution with a pail while another mixed it with a shovel. The pile had to be turned over a few times to mix it thoroughly. A rake was found to be helpful in breaking the lumps as the material was being turned with a shovel. The mixed material was dumped into sacks and piled for delivery.

The adhesive poison bait was made wetter and was stored in five-gallon cans with the tops cut out.

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*Mr. H. C. Atwell, Horticultural Commissioner of the First District in general charge of the campaign. Mr. J. E. Stansberry in charge of field work. B. B. Fulton, detailed by the experiment station in an advisory capacity.

(3) *Transportation.* Trucks were hired to deliver the poison bran bait to the territory to be poisoned. They loaded up at the mixing plant just before 7:00 p.m. and had part of the load delivered before the spreading crew arrived for work. The drivers had small maps of the territory to be covered, with arrows showing the route to take. The sacks of bait were dropped at the curb, two or three piles on opposite sides of the blocks to be treated. Later they went over the same route again and picked up the sacks and unused portion of the bait.

In the case of the adhesive bait which was applied during the day, the truck could haul the whole day's supply and followed the crew without unloading.

(4) *Spreading poison bran bait.* The work of scattering the poison bran over the ground began at 7:00 p.m. and continued until midnight. A spreading unit was divided into two gangs, which worked on the same block but on different streets. If the blocks were longest east and west, one gang would work the north half and the other the south half, and together they would work west on one tier of blocks and east on the next. A gang of ten spreaders, one foreman and one filler, was found to be about the best number for each half unit.

The spreaders carried the bait in canvas sacks with a shoulder strap. Army nose-bags served the purpose very well. The filler would dump the bait into the carrying sacks. A piece of canvas about four feet square was used to catch the spill. The foreman would assign one or two men to each lot, and they were expected to finish the work on that lot before starting on another one. On large vacant property the whole gang would line up along the street about four yards apart with full sacks and then move across the lot, keeping abreast and scattering the bait as they went.

It was found advisable to have a general supervisor over each unit to inspect the grounds after the work was done and see to it that no part was missed.

After dark each man carried a carbide miner's lamp. The filler was also provided with a light iron stake about three feet long, with a sharp point and a step near the bottom for pushing it into the ground. At the top it was fitted with a short piece of pipe which would receive the handle of a miner's lamp.

(5) *Adhesive poison bait.* Since adhesive poison bait was applied in day time and only to trees, buildings, fences, walls, and other objects, the work went much faster than that of scattering the bran bait. It should be used only when the earwigs are half grown or larger. The material was kept in a truck, and the driver had rather large-scale quarter-section maps with the prescribed route indicated on them. He would assign each man a block to work on and write the man's name on the map in that block. A gang of eight or ten was as many as could work together conveniently in one unit. The material is of the consistency of thin dough and is applied with the hands in about teaspoonful quantities.

*Summary of campaign.* In summing up the records of the campaign, we find that about eight hundred city blocks, averaging fifteen lots each, were treated with one application of poison bran, and about two-thirds of this area was also treated with adhesive bait. The total materials used were as follows: sodium fluoride, 15,300 lbs.; wheat bran, 252,000 lbs.; molasses, 47,900 lbs.; glycerin, 858 lbs.; ground oat hulls and other carrier for adhesive bait, 3760 lbs.

The total cost of these materials was close to $6800, and the total cost for labor and all other expenses connected with the control work was $6200, making a grand total of $13,000. With these figures the total cost of one application can be computed at $16.25 per block or a little more than a dollar per lot. This would be a little higher if the adhesive bait had been applied over the entire area.

The Portland campaign of 1923 was carried on under very unfavorable weather conditions. Unusually warm weather in April caused the earwigs to hatch early. Later when control operations were under way the work was interrupted and retarded by frequent periods of cold or rainy weather. This condition continued until July, and by that time the earwigs were beginning to mature.

By continuing the campaign later than was originally planned, it was possible to treat the main infested area with one application of poison bran, and the adhesive bait was applied to trees, etc., over a large part of the area. Wherever the poisoning was done under reasonably favorable conditions, it so reduced the numbers of earwigs that they were no longer troublesome, but they could still be found by searching for them.

## NATURAL CONTROL

The physical conditions of the environment probably modify the distribution of the earwig, but the limiting factors have not been studied. They demand considerable moisture, especially during the early stages, but do not live on land which has standing water during the winter. It has been noticed that they are more numerous on well kept, well watered grounds than on dry fields which are without trees or bushes.

Birds prove to be of little value in the control of earwigs, no doubt due to the nocturnal habits of the insects. Hens eat earwigs readily when they can find them. Brindley[7] has summarized the available data on earwigs as food for birds in England and finds that many of the most insectivorous birds are not reported as feeding on earwigs at all, and in only a few species did earwigs form an important part of stomach contents.

Jones states that toads eat earwigs readily. Since these animals are nocturnal in habits they would seem to be ideal enemies for reducing the number of earwigs. Unfortunately toads are almost unknown in most of the present earwig-infested areas, probably on account of the dry summer weather and scarcity of permanent ponds for breeding places. In the spring of 1924 a number of toads were found by Howard Stearns in an earwig-infested lot in St. Johns. He says that a dissection of three of them showed many unfortunate earwigs in the stomach of each.

Earwigs have a fungous disease in Europe. Brindley says that a disease of this kind caused heavy mortality among the earwigs which he kept in captivity and that in order to keep them alive he had to have dry sand in the glass dishes and supply water only with the food. The writer has had no instances of earwigs dying of fungous disease although some of the cages have been very wet and have even developed mold.

In the spring of 1924, working with the earwig control work in Portland, Mr. Howard Stearns found a few dead earwigs covered with a fungous growth. When live earwigs were confined with these specimens they acquired a disease which manifested itself by difficulty of locomotion, and by a whitish color about the pronotum. After death the diseased individuals became covered with a greenish fungous growth. This fungous was identified by Professor H. P. Barss as green muscardine, *Oospora destructor* (Metochnils) Delacroix, which has been found on white grubs in France and on the beet root weevil, *Bothynoderes (Cleonus) punctiventris* Germar, in Russia, where attempts have been made to disseminate the disease artificially.

There are a number of parasites of the European earwig some of which may prove to be of economic value if introduced into the infested regions. Many earwigs harbor gregarines, protozoan parasites, in the alimentary canal, but these are not fatal to the insect. Lucas* reports scarlet acarine mite on the European earwig. Jones[19] reports that a parasitic, thread-like worm caused the death of ten percent of the earwigs confined in the laboratory at Newport, R. I. The worm (Filaria locustae) lives free in the body cavity of full-grown nymphs and adults. The average measurement of five of these parasites was 3¼ inches by 1/48 inch. So far we have not discovered this parasite in Oregon. A somewhat smaller thread worm was found by Brindley[7] parasitic on earwigs in England, but all the infected individuals seemed as active and healthy as those not infected.

In Europe the larvae of two species of flies (Tachnidae) live as internal parasites in the body of the earwig, and are fatal to it. These are *Digonochaeta setipennis* and *Rhacodineura antiqua.* Investigators at the Rothamsted Experiment Station in England have been engaged in exporting these Tachinid parasites, *Digonochaeta setipennis* and *Rhacodineura antiqua,* to New Zealand and recently arrangements have been made to have them shipped to the United States.†

## LIFE-HISTORY AND HABITS OF THE EUROPEAN EARWIG

In Oregon earwigs can be found in midwinter under boards or stones on the ground or in cavities in the ground an inch or two under the surface, rarely deeper. They do not hide in clusters as they are found in summer, but each one has a small cell with just room enough to move about a little. Strictly speaking the earwigs do not hibernate but are more or less active all winter. Many of the females have a cluster of cream-colored oval eggs, while others are without eggs (Fig. 3). Observations made on January 15, 1923, showed that those with eggs in the cell had no developed eggs in the body, while those found without eggs had the abdomen full of them. One of the latter had 35 developed eggs in the body. The normal number found in the nests ranges from 40 to 60. Actual counts from some nests are as follows: 46, 46, 47, 48, 50, 59, 60.

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*Lucas, W. J., Entomologist. 39, p. 213, 1904.

†No shipment of these parasites to Oregon can be made before the fall of 1924. These will not emerge as adult flies until the spring of 1925 and during that season it will be necessary to breed them in confinement. Under the most favorable circumstances, no parasites could be liberated before 1926, and the effect of their work would not be noticed for several years after that.

Presumably the over-wintering eggs are deposited in the fall or on warm winter days, while those females without eggs earlier deposit them early in spring. A female collected on January 19, 1924, and kept in a warm room was found nine days later with a pile of eggs which had been laid during the night.

The males leave their hibernating quarters very early in spring and seek convenient dark crevices above ground, where they often cluster together in large numbers.

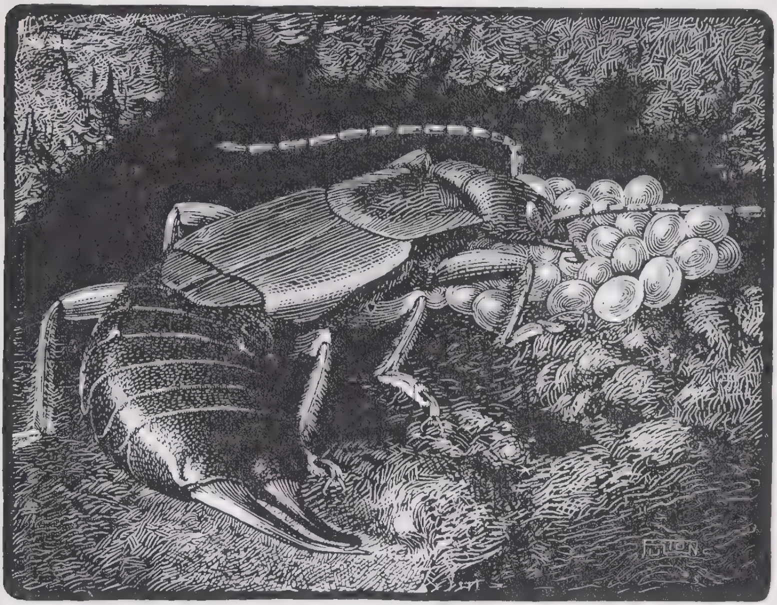

Fig. 3. Female earwig in winter quarters with eggs.

**The egg.** The eggs when first deposited are pale yellow or cream colored and opaque, broadly elliptical, a trifle over a millimeter (1/25 inch) long and slightly under a millimeter in width. The average of six from one lot was 1.085 mm. long by 0.975 mm. wide; three from another lot averaged 1.10 mm. by .84 mm. As the eggs develop they increase greatly in size, become whiter and more translucent. They begin to show watery patches among the general cloudy whiteness of the internal structure. At this stage some eggs measured 1.54 to 1.62 mm. in length by 1.22 to 1.32 mm. in width. When about to hatch the embryo can be dimly seen through the shell (Fig. 4, A). It is curled up with the head in one end and the abdomen doubled under and reaching nearly to the mouth. The dark red eyes, mandibles, antennæ, palps, and legs are plainly visible, and occasionally slight movements of the legs can be observed. At this stage the eggs are still larger and appear to be under pressure. Measurements of seven gave the following: length 1.59 to 1.71, average 1.65 mm.; width 1.22 to 1.32, average 1.27 mm. Something of the internal pressure and the elasticity of the membrane of the developing earwig egg can be demonstrated by dropping one on a smooth hard surface. It will bounce like a new tennis-ball.

When placed dorsal side up under a microscope the heart beat of the embryo can be plainly observed and counted—138 per minute, at ordinary room temperature of 70 to 75° F.

**Maternal care of eggs.** The maternal care of the eggs and young by the female earwig has been described as long ago as the eighteenth century by the Swedish entomologist, DeGeer. He told how he placed a female with her eggs in a sand-box and watched her gather up the scattered eggs and place them in a pile. This is an experiment which any one can easily perform. A flat dish covered with a piece of glass or a Petri dish partly filled with moist sand makes an ideal home for an earwig, where its habits can be observed.

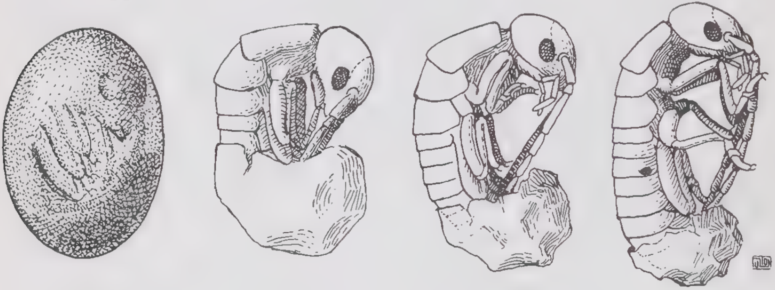

Fig. 4. *A,* Egg about ready to hatch (as seen by transmitted light); *B, C, D,* stages in the hatching process.

After the female earwig has gathered the eggs into a pile she will dig a hole in the sand to store them in, or will make use of some ready-prepared cavity. From then on she stands over the eggs and guards them (Fig. 3).

**Hatching.** During the whole incubation period the eggs are moved about frequently from one part of the cell to another and at each handling the earwig rolls them about in her mouth, as if cleaning them. At hatching time this shifting about becomes more frequent and no doubt the process prevents any newly hatched earwig from being imprisoned under the pile of eggs.

The membrane of the egg becomes greatly stretched with the increase in size of the egg; its area increasing on the average about twice. It bursts at the end occupied by the head of the embryo, which immediately begins the struggle of freeing its parts from each other and from the membrane. The bursting of the membrane must take place very suddenly, for although the writer has observed the hatching of many eggs, he has never happened to be looking at one at the moment the process started. One emerging young was found with the egg membrane caught in the condensed moisture on the glass cover, 6 mm. above the spot where the egg had been a few seconds before, indicating that the hatching had started with something approaching explosive violence.

When the young earwig first appears, more than half the body protrudes from the shriveled egg membrane before it changes its embryonic position. Then it straightens out, and one by one the legs are unfolded and moved about. The first two pairs of legs then push at the antennæ to free the distal end (Fig. 4). The egg membrane remains as a shriveled white thing, clinging to the tip of the forceps, and is finally knocked off by the movements of the young earwig. It takes about three to five minutes for the young to free its legs and antennæ. About two minutes later it can crawl feebly.

**Time of hatching.** Hatching usually begins in April, but it may be early or late according to the season. This applies to nests in warm situations not too deep in the ground. Eggs in shaded places do not hatch until the latter part of April or early in May. For the three years that the earwigs have been under the writer's observation, hatching has started during the blossoming period of the native broad-leaf maple and cherry trees and is practically completed by the time apples are in full blossom. In the spring of 1924 hatching began about the time pear trees were coming into blossom; cherries were in full bloom and the maples had flower clusters about two inches long.

**The nymphs.** The first few minutes of the young earwig's life, after freeing itself from the egg membrane, are concerned with the process of locomotion. It does not even stop to devour the remains of the egg as is customary with many young insects. Crawling is at first feeble and uncertain, but soon the mechanism of its body begins to work more smoothly and the movements become better coordinated. After a while the nymph settles down in a quiet part of the cell to develop hardness and color. It resembles the adult earwig closely except in the structure of the thorax, which has no trace of wings. The body is white and almost transparent. At times the nymph devours quantities of air, which can be seen as a series of bubbles passing through the esophagus. One or more large air vacuoles can be seen through the wall of the abdomen.

In a few hours the young nymph becomes a medium gray color with a slight brownish or olive tinge. The body becomes shorter and broader. The head of the newly hatched earwig measures about 0.9 mm. in width but later measures fully 1 mm. The body back of the head is at first 2½ mm. long but later shortens to 2 mm.

**Maternal care of the young earwigs.** For a few days after the young earwigs appear the female keeps the nest tightly closed to prevent their escape. A nest of young earwigs is a most interesting sight; they seem to fill the cavity, a squirming, writhing mass. The old earwig standing in their midst with the nymphs crawling under, over and about her, reminds one of an old hen with a brood of chicks (Plate I).

After a few days the nest is opened to the outside, but the female guards it against all intruders by using her forceps as a weapon. Occasionally she brings in some food for the young earwigs, who remain in or close to the nest until they have moulted.

**Nymphal instars.** There are four nymphal instars or immature stages of the earwigs. In other words, during the development of the earwig from hatching to maturity it sheds its skin four times. After each moult the nymph is pure white and has a decidedly inflated appearance. This is due to a large quantity of air in the alimentary canal,

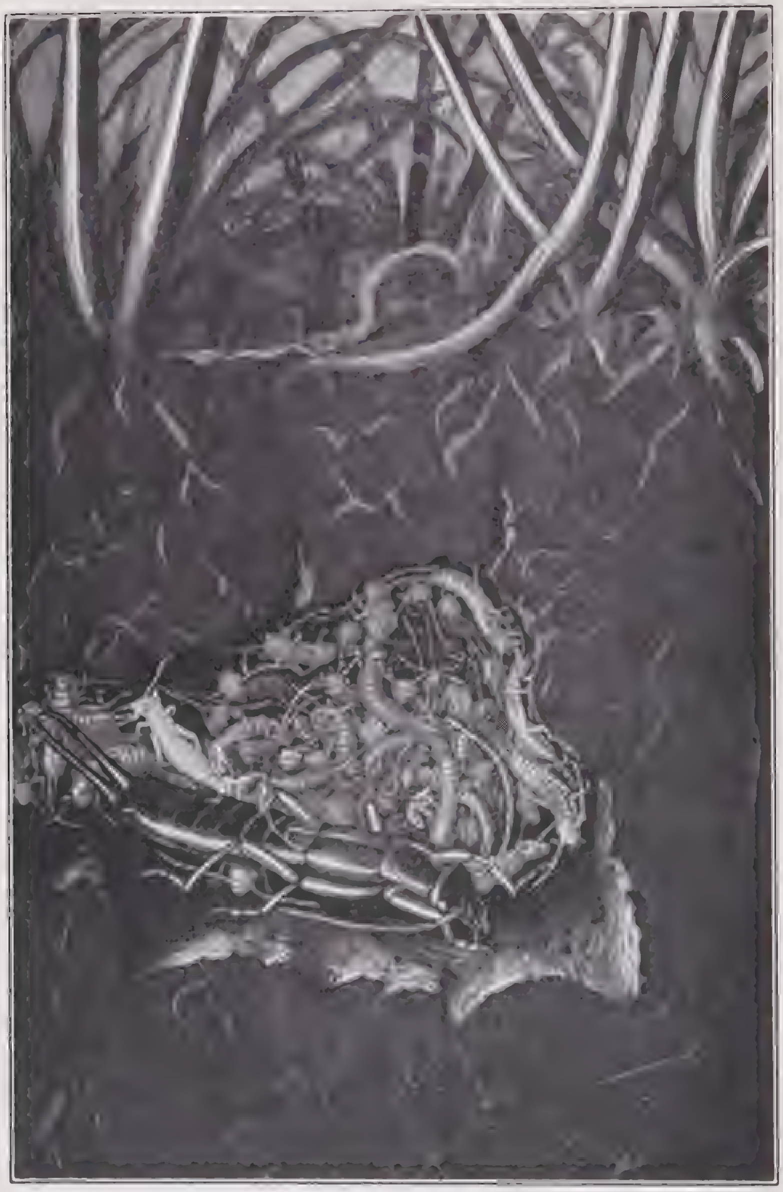

PLATE I. SECTION OF SOD SHOWING AN EARWIG IN UNDEGROUND NEST WITH YOUNG.

which is greatly distended and completely fills the body cavity. The solid contents of the intestine occupy only the extreme posterior end of the body. The air is swallowed by the nymph as was observed in the case of the newly hatched earwigs. After again acquiring the normal gray color the nymph is quite noticeably smaller than during the white period. The purpose of this period of inflation is not clear. It may serve to shape the new integument until it has hardened properly.

The question arose regarding transformations of the wings at the last moult. Although many recently moulted individuals were seen while still white and inflated, yet none were observed in the act of shedding the last nymphal skin. In all of those observed the wings were already fully developed and folded. In a few cases the wings were rather loosely folded, and the part which normally lies next to the body was exposed, each wing assuming a roof-like position. The wings probably expand in this loosely folded condition. The wing pads of earwigs about to moult for the last time show, by the position of the tracheæ, that the incipient wings are already folded along the lines of the adult wing.

The various stages can be distinguished by the changes in the thorax, the number of antennal segments, and the size and shape of the forceps and pygidium. In the thorax of the first instar the segments are transverse and of nearly uniform width throughout (Plate II, 6). In the succeeding instars the pronotum becomes more quadrate; the posterior lateral angles of the metanotum become lobed in the second and third instars, and appear as well developed wing pads in the fourth (Plate II, 7-9). The antennæ in the first instar have 8 segments; in the second instar, 10; in the third instar, 11; in the fourth instar, 12; and in the adult, 14 (Plate II, 10-14). This is the normal number, but it may vary by loss of segments in earlier instars. In the third segment of the antennæ in each stage, the additional segments of the following instar can be detected by a slight constriction in the outline of the segment and by a differentiation in the internal structure.

The forceps in the first instar are straight, delicate, and seem to show a barely perceptible segmentation, like the filiform cerci of many other insects (Plate II, 1). In the second instar they assume the typical curved form, and in succeeding instars they increase in length and relative thickness (Plate II, 2-5). The small piece between the bases of the forceps, known as the pygidium, is broadly rounded and scarcely visible in the first instar, becomes protruding in the second, develops slight lateral angles posteriorly in the third, which become more prominent in the fourth. In the adult the pygidium is quadrate, with parallel sides and rectangular posterior angles.

## COLOR DESCRIPTION OF INSTARS

**First.** Young. Pale gray with brownish olive tinge; darkest at posterior end of body; surface glossy; area around mouth pale reddish brown; head with a narrow pale transverse line between eyes which joins a similar median dorsal line extending across occiput, thorax, and first abdominal segment; legs and forceps translucent, integument only slightly infuscated; antennæ a little darker than the legs. Older nymphs of the first instar are a medium brownish olive.

**Second and Third.** Medium dark, brownish olive, the third instar slightly darker; darkest at posterior part of abdomen; ventral side and legs very pale brown; labrum and mandibles tinged with reddish brown; forceps pale brown at base, distal two-thirds very dark.

**Fourth.** Dark olive brown, darkening toward posterior part of body where it is nearly black; clypeus and mouth parts except palpi, reddish brown; thorax medium dark in median area; tegmina developing along lateral edges of mesonotum pale brown; wing pads which occupy nearly whole visible portion of metanotum, very pale brown; legs very pale olive brown and translucent; forceps pale and translucent at base, distal two-thirds or more dark brown or black; antennæ medium or dark olive except the two basal segments which are pale.

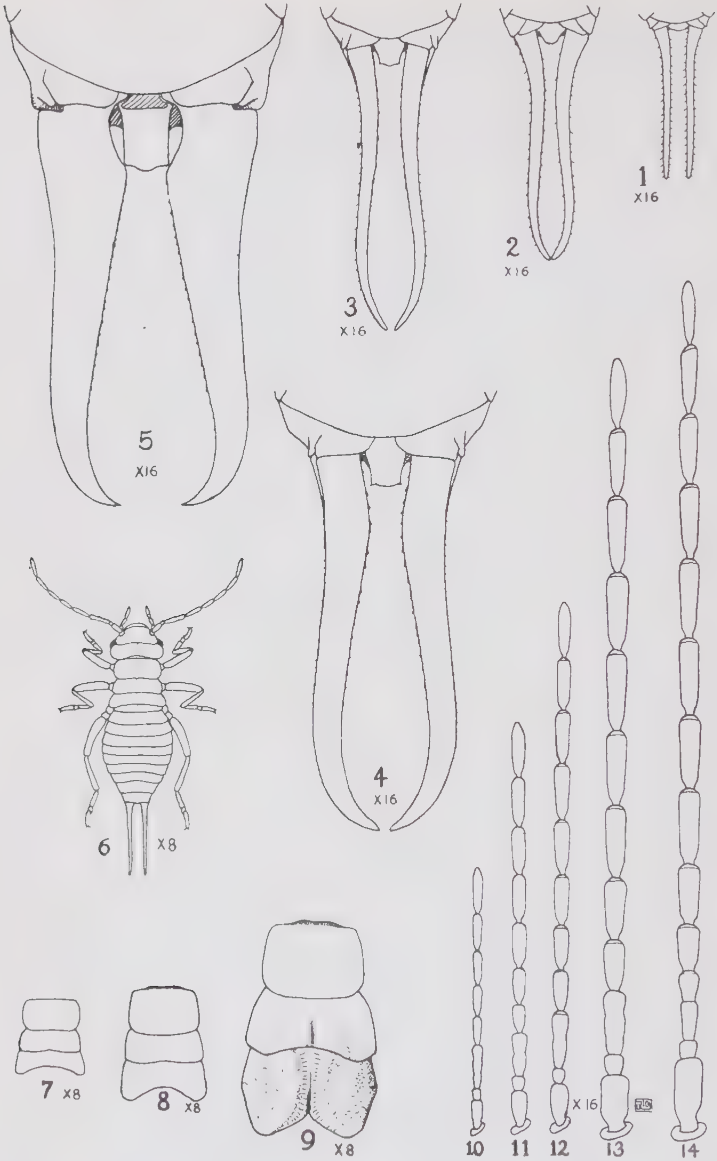

Plate II. 1-4, Forceps of the Four Nymphal Instars, Respectively. 5, Forceps of Adult Female. 6, First Instar. 7-9, Thorax of Second, Third, and Fourth Instars Respectively. 10-14, Antennæ of the Four Nymphal Instars and Adults, Respectively.

MEASUREMENTS OF INSTARS (IN MILLIMETERS)

(Alcoholic specimens)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| FIRST | Body | 2.7 | 2.8 | 3.9 | 4.0 | ------- | ------- |
| | Antennæ | 1.96 | 2.25 | 2.30 | 2.45 | ------- | ------- |
| | Forceps | 1.22 | 1.27 | 1.32 | 1.42 | ------- | ------- |
| SECOND | Body | ------- | 4.6 | 5.0 | 6.0 | ------- | ------- |
| | Antennæ | 2.89 | 3.38 | 3.43 | 3.52 | 3.72 | 3.80 |
| | Forceps | 1.70 | 1.80 | 1.90 | 1.96 | 2.01 | 2.10 |
| THIRD | Body | 7.0 | 8.0 | ------- | ------- | ------- | ------- |
| | Antennæ | 4.28 | 4.46 | 4.65 | 4.90 | 5.00 | ------- |
| | Forceps | 2.40 | 2.45 | 2.49 | 2.54 | ------- | ------- |
| FOURTH | Body | 8 to 11 | ------- | ------- | ------- | ------- | ------- |
| | Antennæ | 4.40 | 6.27 | 6.30 | 6.37 | ------- | ------- |
| | Forceps | 2.84 | 2.94 | 3.08 | 3.18 | ------- | ------- |
| ADULTS | *Female* | | | | | | |
| | Body | 10, 11, 11, 11, 12, 12, 12.5, 13, 13, 14, 14, 14, 14, 15, 15, 15. | | | | | |
| | Antennæ | 14 segments, 7.4; 13 seg., 6.4, 6.5, 7.0; 12 seg. 5.7, 6.0, 6.6, 7.0. | | | | | |
| | Forceps | 3.0, 3.0, 3.4, 3.4, 3.5, 3.6, 3.6, 3.6, 3.7, 3.8, 4.0, 4.0, 4.2. | | | | | |
| | *Male* | | | | | | |
| | Body | 10, 10.5, 11, 11, 11, 11.5, 11.5, 12, 12, 15, 15. | | | | | |
| | Forceps | 3.6, 3.8, 4.0, 4.0, 4.0, 4.3, 4.8, 4.8, 5.8, 5.8, 6.2, 6.8. | | | | | |

**Life of the earwig nymph.** During the first instar the young earwig remains close to its home. If it ventures out at all it is for a very short distance and time. In the second instar the nymph is stronger, can run quite rapidly, and is well equipped to take care of itself. The nymphs begin to make nightly trips away from the nest. Especially on warm nights they may be seen swarming out in large numbers. Young earwigs that were disturbed while feeding have often been observed carrying particles of food away with them as they scurried for cover. Whether they always return to the same nest after a foraging trip is not known, but another nest would do as well, for it has been observed that the young earwigs are quite welcome in a strange nest.

By the third instar at least, all family connections are broken, the earwigs intermingle promiscuously, old and young, in any convenient hiding place. At night they come out again and wander far in search of food. They no longer remain on the ground but seem to prefer to climb any object within reach. They will be found swarming up the side of houses, on fences, bushes, trees, even to the terminal branches. When daylight approaches they will descend far enough to find a suitable hiding place, under loose bark, or among rubbish in the crotch of a tree, in cracks about buildings or in fences, posts, or walls. Earwigs of all ages show a gregarious instinct and love to hide where there are more of their kind. Hiding places become more attractive after they have been used, probably because they become thoroughly imbued with the peculiar odor of earwigs.

**Broods.** The majority of earwigs hatching from the over-wintering and early spring eggs mature in the latter part of June. The over-wintering adults become scarce when the young are half-grown in late May or June. It has been thought that they die off before their offspring mature. This may be the case with many of them, for dead adults can be found at that time.

Recent observations of the author on caged earwigs show another explanation for the disappearance of adults in early summer. Of the eleven females brought into the laboratory with their eggs in early spring, five of them closed up the nest again and deposited a second batch of eggs after the first brood had reached the third instar or had died. The number of eggs appeared to be only about half of the usual number found during the winter. Two of the sets contained 25 and 27 eggs respectively, but the others could not be counted without breaking up the nest. One of the females, taken from the ground with her first eggs on January 19, had raised the first brood in the laboratory during February and deposited the second set of eggs as late as April 16. Another nest, which contained a large family still in the second instar, was found one morning to be deserted except by the adult, which had blocked out the young ones and deposited a second set of eggs. In the other cases the second brood eggs were deposited while the young were in the third instar. One lot of the second-brood eggs all hatched after about 20 days, another lot partly hatched after 13 days, and one lot failed to hatch. The other two sets disappeared after a few days and the nests had been invaded by the large nymphs of the first brood, which probably devoured the eggs.

The females which did not deposit a second lot of eggs died before their first brood matured. Two of them were examined after they died and their ovaries were found to contain undeveloped eggs about a third as long as fully developed eggs. Many adult females were found in the spring of 1923 which had the bodies full of well developed eggs. On May 9, 1924, adult earwigs were examined in Portland, and most of the females were found to contain eggs, some very small but others apparently fully developed. Some of the adults had apparently holed up for the purpose of oviposition, but no eggs were found. Most of the young earwigs of the first brood were in the second instar at that time.

These observations indicate that at least a large number of adult females go into the ground again some time in June and rear a second brood of young. They also explain why newly hatched earwigs appear occasionally during early summer when the rank and file of earwigs are nearly mature. In 1923 first instar nymphs were found on July 14 and earlier, when the main brood had already reached maturity.

By the first of September all earwigs are found to be in the adult stage. The author made no observations on the earwig out of doors between the middle of July and the first of September, but feels sure that there is but one generation a year and that the females of the new generation do not make nests until fall. The second brood of young is probably much smaller than the first. Poisoning operations carried on during the time the first brood is in the second instar should poison the adults before any of them retire to raise the second brood.

The following observations on the life-history of the earwig, made by Mr. Howard Stearns in Portland in the spring of 1924, confirm the foregoing conclusions regarding the two broods. The last day eggs were found out of doors was April 21. Eggs collected on this day and earlier had all hatched by April 23. On April 24 all but a few of the young earwigs were in the first instar. On May 2 a number of females were opened and about 90 percent were found to contain eggs, an average of 30 each. From then on few females were found which did not contain eggs. By May 10 many of them had well-developed eggs, indicating that oviposition would soon take place. On May 13 two females in the laboratory deposited 40 eggs each. By May 22 no eggs had been found in the field, but most of the females had holed up in the ground. No accurate data were obtained on the proportion of females which lived to produce a second brood, but observations in the field indicate that at least 40 percent did so. By May 22 most of the males had died; this was true at least of those in captivity, and few could be found in the field. At that time most of the young of the first brood were in the third instar; a few were in the second or fourth instars but probably none had matured.

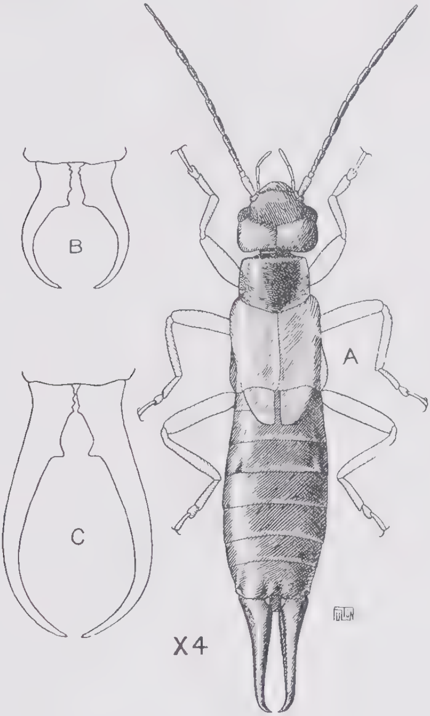

Fig. 5. *A,* Adult female earwig. *B, C,* Forceps of small and large males.

**Description of adults.** The adult female earwig (Fig. 5) is about 16 mm. or ⅝ inch in length including forceps when alive. In dead specimens shrinkage of the abdomen reduces the length. Males are about the same size or considerably larger. The general color is dark reddish brown; head decidedly reddish (burnt sienna); wing covers, wings, and edge of pronotum medium yellowish brown; center of pronotum practically black; legs pale yellowish-brown, forceps pale at base, black on distal part and along both lateral edges.

The forceps differ greatly in the two sexes. Those of the female are about 3½ mm. long, nearly straight on the inner edges and curved inward at the tips so that they cross over when closed (Fig. 5, A). The male forceps have wide flat bases, beyond which they are strongly arcuate and caliper-like. The males are dimorphic in regard to the size of the forceps (Fig. 5, B, C). The great majority of them have forceps ranging either about 3.5 mm. in length or about 7 mm. Brindley records a male with forceps 12.25 mm. long. The males with the long forceps are usually much larger in body. They have been referred to in taxonomic literature as variety *forcipata.* The proportion of males with large or small forceps varies with different localities.

On each side of the dorsal aspect of the fourth abdominal segment (third visible segment) is a small fold in the integument, and the border of the tergite is notched at that point. A similar but smaller structure is located on the third segment. These folds mark the orifices of certain glands which are probably responsible for the peculiar odor characteristic of earwigs. If an earwig is picked up small drops of liquid are sometimes discharged from these glands. It spreads over the body of the earwig and dries rapidly. If wiped off with the corner of a piece of paper it imparts a brown color. In cleaning the body the earwig often passes the hind tarsi over these glands and back along the abdomen. It is possible that the liquid from the glands may serve to clean the body and lubricate the segments.

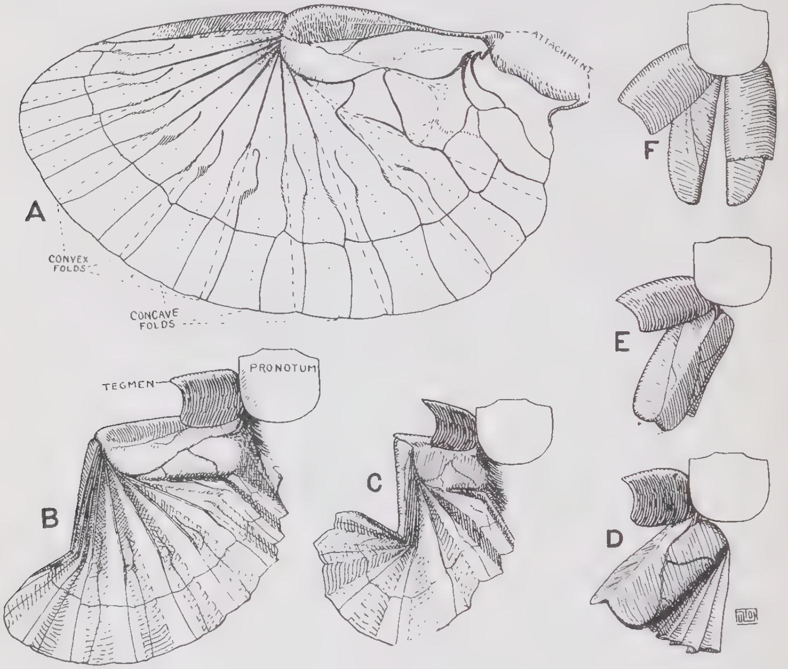

Fig. 6. *A,* Spread earwig wing. *B, E,* Stages showing process of folding the left wing. *F,* Both wings completely folded, left tegmen raised.

The wing of the earwig is one striking feature which is seldom observed. The hind wings are tightly folded and only a small part shows, protruding from under the tegmina, or modified fore wings. To unfold one of the wings is a rather difficult feat to accomplish without tearing or crumpling the delicate membrane. The system of folding is complex.

A point on the costal margin of the wing, a little over a third of the way from the base, is the focus of a series of radial folds which spread fanlike over the major part of the area (Fig. 6). The basal area is divided by a main longitudinal fold which also meets the focus of the radial folds. When folded the distal or radial part of the wing resembles a closed fan which has been folded again transversely or doubled upon itself, and the whole is enclosed within the main fold of the basal area, which is of heavier texture and serves to protect the more delicate parts. It can best be described by likening the wing to a fan which opens out in the form of a semi-circle but which has the ends of the rays trimmed off shorter on one side. Imagine that it is attached to the body by the ends of some of the shorter rays, that the handle lies in the anterior or costal margin, and the longer rays extend posteriorly and outwardly. As it closes, the ends of the longer folds would strike the body, but this is avoided by a cross fold so that the tip of the fan when closed is doubled upon itself and lies near the handle. Then imagine that the last fold of the fan on the short, attached side is much broader and of heavier texture and that the rest of the fan when closed is tucked away inside of this fold, and you have a fair idea of the mechanism of the earwig wing.

**Flight.** There has been much discussion in literature about whether *Forficula auricularia* can fly. The Little earwig, *Labia minor,* which is also found in Oregon, has frequently been seen flying. Collinge[12] records the flight of *Forficula auricularia* in England. On three warm, sultry evenings about the first of July a number of male earwigs flew into his house between 9:30 and 10.30. In Oregon the flight of the European earwig must certainly be a rare phenomenon, for so far as the writer knows it has never been observed here, in spite of the enormous number of the insects.

**Reaction to light.** Earwigs are not normally attracted by light of any intensity. They do not become active until it is thoroughly dark. They are disturbed by an artificial light as weak as the ordinary pocket flashlight, which can be thrown on most nocturnal insects without causing them to depart from their normal activities.

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Station Bulletin 208 August, 1924

Oregon Agricultural College

Experiment Station

# Filberts

## PART I. GROWING FILBERTS IN OREGON
## PART II. EXPERIMENTAL DATA ON FILBERT POLLINATION

By

C. E. SCHUSTER

1885

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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## FILBERTS

Plant the Barcelona variety, with proper pollenizers in deep, fertile, well drained soils.

Use trees propagated by layerage. Good cultivation, fertilization, pruning, and pollination must all be provided for and kept up.

Oregon has enough good land on which to grow filberts so that doubtful locations should be avoided.

## SUMMARY

Filberts need deep, fertile, well drained land. Frosty locations are no drawback to growing filberts.

Plant early in winter or spring at distances of 20 to 25 feet. Set as shallow as possible but still deep enough to keep the roots in moist soil during the summer months.

Cultivation as for other fruits will be found necessary for best results. Heavy production will be necessary to compete with foreign importation.

Propagate trees by layerage from known, proved trees. Propagation and nut production do not go together except when very high prices are being obtained for nursery trees.

Thinning out in pruning is the best practice. Supplement pruning with good cultivation and fertilization for tree vigor and growth.

Pick all nuts from the ground promptly, and dry to avoid molding. Do not put wet nuts in sacks or heaps.

Bacterial filbert blight is best controlled by cutting out infected parts. Bud mite and aphis can be controlled by proper sprays.

A uniform system of grading should be established.

The stigmas of Corylus avellana have a long period of receptivity for pollen.

Pistils may be injured at temperatures of 12° to 15° F. Pollen will stand several degrees lower temperature than 12° to 15° F. at maturity.

Varieties of filberts can be considered as self-sterile from a commercial standpoint. A few are intersterile.

Use White Aveline, Daviana, Du Chilly, and Nottingham when available to pollenize the Barcelona, which is the commercial variety.

Best pollenizers for Du Chilly are Daviana, Alpha, Clackamas, and Chaperone.

Light bearing of Daviana is due more to bud mite than to lack of cross-pollination.

Use one tree in nine as a pollenizer. More will be useful in adverse seasons.

Attempts to cross-pollinate between Corylus avellana, Corylus colurna, and Corylus Californica were failures. Wild hazel has never proved beneficial in pollination of a filbert planting.

# Filberts

By

C. E. SCHUSTER

## PART I. GROWING FILBERTS IN OREGON

The filbert has been cultivated from early days. Pliny[7] narrates: "Filberts and hazels which also are a kind of nut and were called heretofore Abellinae, of their native place. . . . They come out of Pontus into Natolia and Greece and therefore they be called Pontick nuts. . . . These filberts likewise are covered with a soft bearded husk, and as well the shell as the kernel is round and solid, all of one entire piece." He refers to Cato and Theophrastus as early writers mentioning hazels. The filbert was connected with European mythology and witchcraft, and even today with many people a hazel wand is used in locating underground water.

The name filbert is supposed by some to have originated from "full beard" referring to the husk entirely covering the nut. By others it is thought to have been derived from St. Philibert, as August 22 is dedicated to him, which date corresponds in England to the ripening date of the earliest filberts.

### DISTRICTS ADAPTED TO FILBERTS

The Willamette Valley and corresponding territories in Washington have been proved suitable for filbert growing. Here the filbert has been growing for nearly three decades, and results warrant the belief that filberts will be a commercial success in these places. There may be other districts to which filberts will be found to be adapted, but those places have not yet been thoroughly tested out. The Experiment Station has been sending out trial lots of filberts to different parts of the state of Oregon in the endeavor to determine, if possible, the feasibility of filbert growing in places other than the Willamette Valley. Planting in other sections must be considered at the present time as more or less an experimental venture; it would not seem advisable, therefore, to enter upon large plantings in those places.

**Location.** Filberts can be grown on different locations, including foot-hills and river bottoms, provided the requirements of soil, as indicated later, are complied with. As the pistillate flowers, which are the tenderest to cold of any part of the tree, can withstand temperatures of 12° to 15° F. when in full bloom, frosty locations are not prohibitive to filbert planting. It may be that these colder places will more readily reach temperatures below 12° to 15° F. and for that reason may not be so desirable as the higher plantings. So far as ordinary frosts are concerned, however, frosty locations can be used for filberts where not suitable for other fruits.

### SOIL

The exact type of soil best adapted to filberts will vary with the different districts, but should be deep, fertile, and well drained.

**Depth.** Soil is considered deep enough for filberts when it is four feet or more in depth. Such a depth insures capacity for the storage of sufficient moisture throughout the summer. This depth of soil should be considered as the depth above rock, impervious hard-pan, or water-table.

**Fertility.** A large amount of fertility is essential to the proper development of the filbert tree. As the fruit is usually borne laterally on one-year-old wood, plant food should be present in sufficient quantity so that, with a plentiful supply of moisture, a good vegetative growth can be obtained each season. Attempts to obtain this growth by means other than high fertility will in the end meet with failure. Other methods, such as heavy pruning, may be temporarily successful, but cannot be depended upon permanently.

Fertility can best be maintained in an orchard by the use of cover crops. The use of cover crops in the early life of a planting will insure the maintenance of fertility, and at the same time, by the presence of humus, will maintain the moisture-holding capacity of the soil. The use of barnyard manure is beneficial at all times if obtainable.

Commercial fertilizers are to be considered as supplementary to the cover crop system. Where the soil has been badly depleted of plant food, commercial fertilizers can then be used temporarily, or until the cover crops have begun to build up the soil. In many cases the soil becomes so poor that commercial fertilizers are of direct benefit in obtaining a growth of the cover crop. For greatest benefits from the cover crop it should be sowed as early in the fall or late summer as possible and then plowed down early in the spring to insure a thorough decomposition without the use of large amounts of moisture during the summer time, when the moisture is required by the trees. It is frequently the case that with the poorer soils it takes several years before a satisfactory cover crop can finally be grown.

**Drainage.** Filberts will not thrive in water-logged soils. The trees will survive under very adverse conditions, but the growth and the crop will be in proportion as the conditions approach the optimum for filberts. While the fruit is a hard nut, the presence of plenty of moisture is necessary for the development of good size in the fruit. The filbert roots make a very extensive growth during the winter time in Western Oregon, but if the soil is water-logged this growth is retarded, or entirely inhibited. All growth of the tree is dependent on the formation of new rootlets and root hairs, and when this is prevented, to a large extent by excess water, growth is correspondingly decreased. As a result of the decreased root growth, when the demand comes during the growing season, or in the summer, for large amounts of plant food and moisture, the root system has not made the increase to allow a good vigorous growth of the top.

It has often been stated that filberts will do well where the wild hazel grows. Without doubt where the very large, vigorous wild hazel grows, there filberts will grow well. It is very frequently found, however, that wild hazel will grow in many places, but the growth is such that the tree is nothing but a shrub. If planted in such places, the filbert will behave in a similar manner, so that the planting of filberts where the wild hazel grows should be only in those locations where the hazel grows very large and very vigorously.

With the plantings going on at the present time, and with the importations coming in from the foreign countries, it would seem without doubt that competition in the filbert industry will be as keen as in other lines of fruit growing, so that the orchards located where the production will be only average or below, will in many cases prove unprofitable. There is enough fertile land in Oregon to grow all the filberts needed without locating on soil that is doubtful in depth, fertility, or drainage.

## VARIETIES

Some classify cultivated varieties of Corylus avellana, Corylus maxima and Corylus pontica into filberts and cobs according as to whether or not the husk covers the nut completely. Goeschke[4] uses the terms Lambertnuss and Zellernuss to cover the same grouping. In actual practice none of these classifications holds without exceptions. In this country the name filbert is taken to mean any of the cultivated varieties derived from the Genus Corylus.

According to Bailey[1] the varieties of filberts now grown were derived from either Corylus avellana, Corylus maxima, Corylus pontica, or as hybrids of two or more of these species. These species overlap in their native habitats, so that it is justifiable to believe that our varieties are hybrids between these three. Observations of seedlings raised from any variety would bear this out, as seedlings from any variety will vary as to shape, length of husk, and other botanical characteristics. It would seem advantageous for clearness of meaning, to classify the filbert as *Corylus avellana* when referring to those varieties introduced from Europe. As yet only one variety has been brought out that has been produced from an American species, and it has nothing to recommend it as a commercial variety.

Of the many varieties tried out in the Pacific Northwest, few have shown any promise. A variety for this country should be one with a large, vigorously growing tree that produces heavy crops. The nuts should be large, well filled, thin shelled, and should drop freely from the husk. None of the varieties tried out has carried all of these characteristics. In the future a more desirable variety may be found.

In describing the varieties of filberts it must be understood that considerable variation occurs in vegetative and fruit characteristics. The exact shapes of the nut is modified by the number of nuts in a cluster. Where several nuts are borne in a compact cluster, the nuts will be more angular, with a rougher, more pointed basal scar than where a nut is borne singly. Length of husk will vary with the vigor of the tree, vigor of individual shoots, and according to the protection given from the elements.

## DESCRIPTION OF VARIETIES

**Alpha.**

Tree, vigorous, spreading, light bearing; nut medium size, blunt oval with a slight tip. Husk two-thirds as long as the nut, curving back from the nut. Of value as pollenizer for Du Chilly. The original tree is at A. A. Quarenberg's place at Vancouver, Washington.

**Barcelona.** (Grosse Blanche, Grosse Blanche de Angleterre, Rogue Ronde.)

Tree spreading, vigorous, productive; nut medium to large, oval to triangular in cross-section outline; base fairly flat, swelling out above and coming to more or less blunt point. Shell medium thick; color rich brown with darker striping lost in pubescence on upper one-third of shell. Husk one-third longer than nut, opens and sheds nut freely. One to eight nuts in a cluster. Introduced by Felix Gillette in 1885 as Grosse Blanche de Angleterre, renamed by him Barcelona. In 1895 he had listed the Barcelona from Spain. Felix Gillette claimed them to be identical.

The Barcelona is the commercial variety grown in Oregon.

**Bergeri.** (La Bergeri.)

Tree medium size, spreading to drooping. Nut medium to large; long to conical, flattened at apex; color light brown with dark stripes in grooves; shell thin. Husk trifle longer than nut. Introduced by Jacob Mackoy of Liege about 1860-70.

**Brixnut.**

Nut large, round, light colored, shell medium thin to thin. Seedling raised by C. T. Brixey of McMinnville. The original tree is not old enough to show definite characteristics. It is a new variety on trial.

**Brunswick.** (Brunswick Aveline.)

Practically identical to Du Chilly, being possibly a strain of the Du Chilly. Introduced from Belgium by United States Department of Agriculture. Sent to Felix Gillette in 1898.

**Chaperone.**

Nut small to medium; long with rather square shoulder and base; flattened on two sides, especially toward tip. Shell thin. Of value as pollenizer for Du Chilly. Seedling raised by C. T. Brixey of McMinnville, Oregon.

**Clackamas.**

From H. A. Kruse of Sherwood. Appeared in a lot of trees bought as named varieties that were not true to name. Good pollenizer for Du Chilly.

**Cluster.**

Much like White Aveline but somewhat larger.

**Cosford.** (Miss Young's Thin Shelled.)

Tree vigorous, upright, close growing, light producing; nut medium to large, oval in length, almost round in cross-section; shell smooth, thin, light brown color with distinct striping. Husk a trifle shorter than nut. Has proved a good pollenizer for Barcelona. One tree at Corvallis in College Orchards. Came to notice in England in 1816.

**Daviana.** (Des Anglais.)

Tree vigorous, upright, close growing, very light producing. Nut very similar to Cosford. Tree very subject to bud mite. Has proved good pollenizer for Barcelona and Du Chilly. A seedling raised by Richard Webb of Calcot Gardens. Introduced by Felix Gillette in 1888.

**Du Chilly.**

Tree, medium vigorous, spreading, growth distinctive as shoots tend strongly to come out at right angles. Production medium. Nut large, long, flattened; shell medium thick, slightly rough. Husk one-third to three-fourths longer than nut. Nut does not drop freely. Pollenizer for Barcelona. Introduced from France by Felix Gillette prior to 1887.

**Du Province.** (Clarke County Cob.)

Tree vigorous, spreading. Nut small, round. Shell medium thick. Husk trifle longer than nut. Too small to be of value.

**Fertile de Coutard.**

Tree fairly vigorous, spreading bushy top; production light; nut medium size; light grayish brown with faint striping. Shell thin. Bud mite bad. No value.

**Geant de Halle.** (Hall's Giant.)

Tree vigorous, upright, spreading. Production light. Nut large, dark brown, slightly rough. Shell medium thick. Originated in 1788 by C. G. Buttner.

**Imperial de Trebizonde.**

Tree medium size, growth very irregular and scraggling. Productive. Nut large; oval at base, tapering sharply to a point. Color light brown, glistening, bright. Husk twice as long as nut, slightly closing in over nut. Variety of no particular value.

**Imperatrice Eugene.** (Empress Eugene.)

Tree upright and spreading. Not very productive. Nut medium to below in size, cylindrical, tapering abruptly at top; color light brown with distinct fine stripes. Husk almost as long as nut. Of no value except as pollenizer for Barcelona, one season's test having shown excellent results. Sent by United States Department of Agriculture in 1895 to Felix Gillette. Introduced from Belgium.

**Kentish Cob.** (Cob, Cob-nut.)

As grown in this country this is very similar to Du Chilly. If different it is but a strain of the Du Chilly. It does not cross-pollenize with the Du Chilly and gives the same results as the Du Chilly in pollenizing the Barcelona.

**Kruse.**

Tree fairly vigorous, productive, nut large, of Barcelona type with very pronounced stripes. From Homer Kruse of Sherwood, Oregon.

**Macrocarpa.**

Tree fairly vigorous, upright spreading. Not very productive. Nut large, with broad base gradually tapering until a short way from top when the angle is sharp. Of no particular value.

**Merveille de Bolwyller.** (Wunder von Bolwyller, Merveille de Bollwyller, Geante de Halle, Geante de Calle.)

Tree vigorous, upright, close grower. Production light. Nut large. broad at base with gradual curve to tip, smooth surface. Color light brown. Husk one-half to three-fourths as long as nut. Introduced by United States Department of Agriculture from Belgium. Sent to Felix Gillette in 1898. Has been confused with Geant de Halle but is conspicuously different in the red pointed bud so prominent in the winter time.

**Montebello.**

Tree moderately vigorous, upright, productive. Nut medium size; pinched in at base, very flat on apex; color grayish brown with distinct stripes; shell medium thick. Is being tested as pollenizer for Barcelona. Introduced from Sicily by United States Department of Agriculture. Sent to Felix Gillette in 1905.

**Noce Lunghe.**

Tree moderately vigorous, open spreading. Production light, nut medium to large, flattened at apex; color very light brown; shell medium thick. Of little value.

**Nottingham.**

Tree vigorous, upright, close growth and fairly productive. Nut medium to small, long, slightly flattened, increasing in width up to two-thirds of length then abruptly tapers to point. Color dark brown, with very fine striping. Shell thin. Husk one-third longer than nut; nut drops freely. One of best pollenizers for Barcelona.

**Pearson's Prolific.**

A variety recently introduced for testing out but about which little is known.

**Pearson's Early Red.**

Nut large, long, slightly flattened. Shell medium thick. Husk longer than nut. (Description from nuts sent in by Robert Gellatly of Gellatly Landing, B. C.)

**Piedmont.**

Tree medium vigorous, productive.. Nut small, nearly round; color very light brown. No value. Probably the oldest named variety tree on Coast, having been planted by Felix Gillette in 1871.

**Princess Royal.**

Tree vigorous, upright, dense, not productive. Nut medium to large, long, flattened toward apex. Color light brown, often with darker stripes in grooves. Of no value.

**Prolific Filbert.** (Frizzled nut.)

Nut small, long pointed. Husk deeply cut and frizzled. Of no value commercially.

**Purple Aveline.** (Purple filbert.)

Tree a weak grower; low, round headed; production light. Nut small, long. Kernel has a light red to pink skin. Tree is distinguished by purple foliage in the spring which loses its brilliance as season progresses. Of value as an ornamental shrub. Introduced by Bauman Bros. of Bollwiller as Corylus Atropurpurea nova. Exact origin unknown.

**Red Aveline.** (Red filbert.)

Tree weak; low spreading growth; production light. Nut small, long. Kernel has dark red skin. Leaves are reddish in spring, practically losing this later on. Of no value. This, with the White Aveline, was one of the first filberts to be cultivated.

**Roberta.**

Originated by H. A. Kruse of Sherwood.

**White Aveline.** (Aveline Grosse Ronde, White filbert.)

Tree medium size to smaller, fairly vigorous; production medium. Nut distinguished from Red Aveline by white skin of kernel. Catkins have grayish yellow color as compared to the red or purple of Red and Purple Aveline. Excellent pollenizer for Barcelona.

## PROPAGATION

Filberts can be propagated in several different ways. Only one or two methods are commercially practical. Except where the prices are as high as those received the past three to four years, propagation can not be advised in a nut-bearing orchard. Propagation is detrimental to the tree and from a nut-producing standpoint is not justified. Where the grower is aiming to produce an orchard that will be a heavy producer of filberts, the suckers should be kept down and not used in propagation. For the last few years, however, the prices of nursery stock for planting of orchards have been such as to justify any one in propagating to the limit regardless of the effect on the trees. This will hardly be true as greater numbers of people enter upon the nursery line with filberts.

**Seedlings.** Trees raised from seed are generally of little value. An occasional tree may show merit, but the greater number will be of type inferior to the parent tree. Each tree will have an individual group of characteristics and may or may not have characteristics similar to the parent tree or similar to the other trees raised from the same lot of seed. The use of seedling filbert trees is comparable to the use of seedling apple trees.

**Suckers.** From the base of the tree, or the crown, numerous suckers will grow up. If the earth is heaped up around the base of these shoots they will in time take root (Fig. 1). This is probably the simplest method of propagating the filbert. By this means a smaller number of trees are raised than by other methods. Propagation by suckers and by layerage, as described later on, can only be carried on with those trees that have been propagated in a similar manner. The use of layerage, or suckers, from trees that have been grafted or budded can not be advised due to the fact that the roots from which the suckers will arise are of a seedling nature, and therefore the new trees will not come true to the varietal name.

**Cuttings.** From the earliest writings up to those of the present time directions were given for the production of trees from cuttings. The cuttings to be used were those 8 to 12 inches long, taken in the fall and then handled as is usual with other cuttings. Experience has proved this to be a rather poor method. Only a small percentage will root, and these will usually be found to be the basal cuts. As the suckers stand in the ground a certain portion of the lower bark becomes lighter in color than the upper part. A cutting with that section on it, or even when the whole sucker is used, will be apt to take root and in time make a tree. Cuttings made from above the ground will not root under ordinary conditions. Where the basal cuts are used, from 20 to 50 percent of the cuttings will take root, but where cuttings are included from that section of the shoot above ground, the percentage decreases according

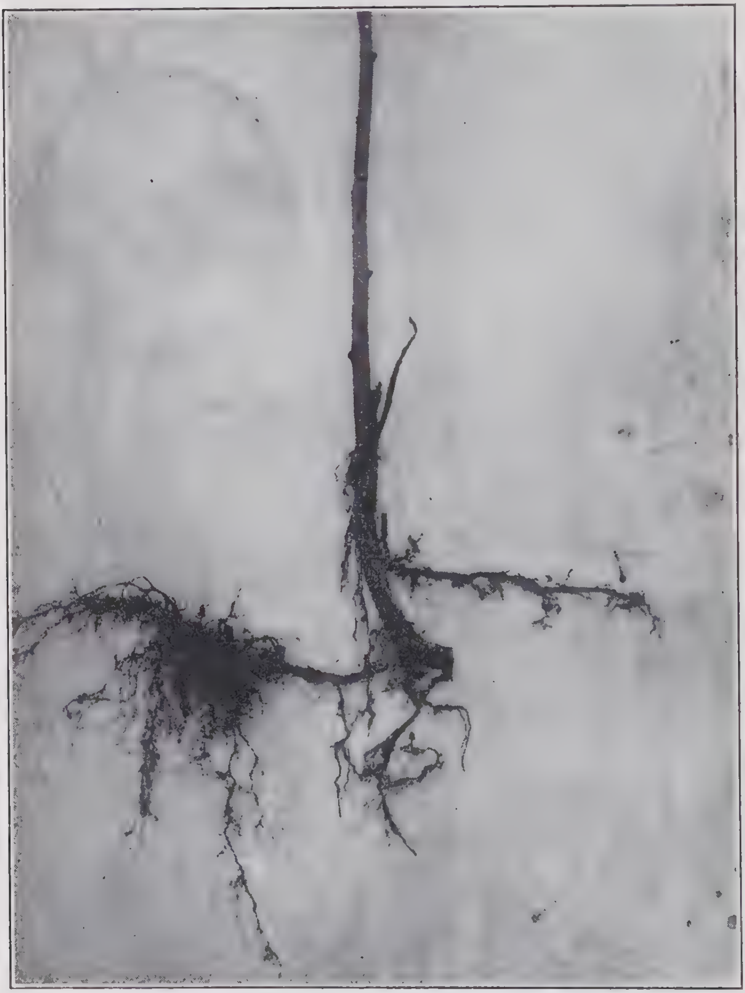

Fig. 1. Young tree raised from sucker without layerage.

to the number of cuttings from the upper part of the shoots that are made and used.

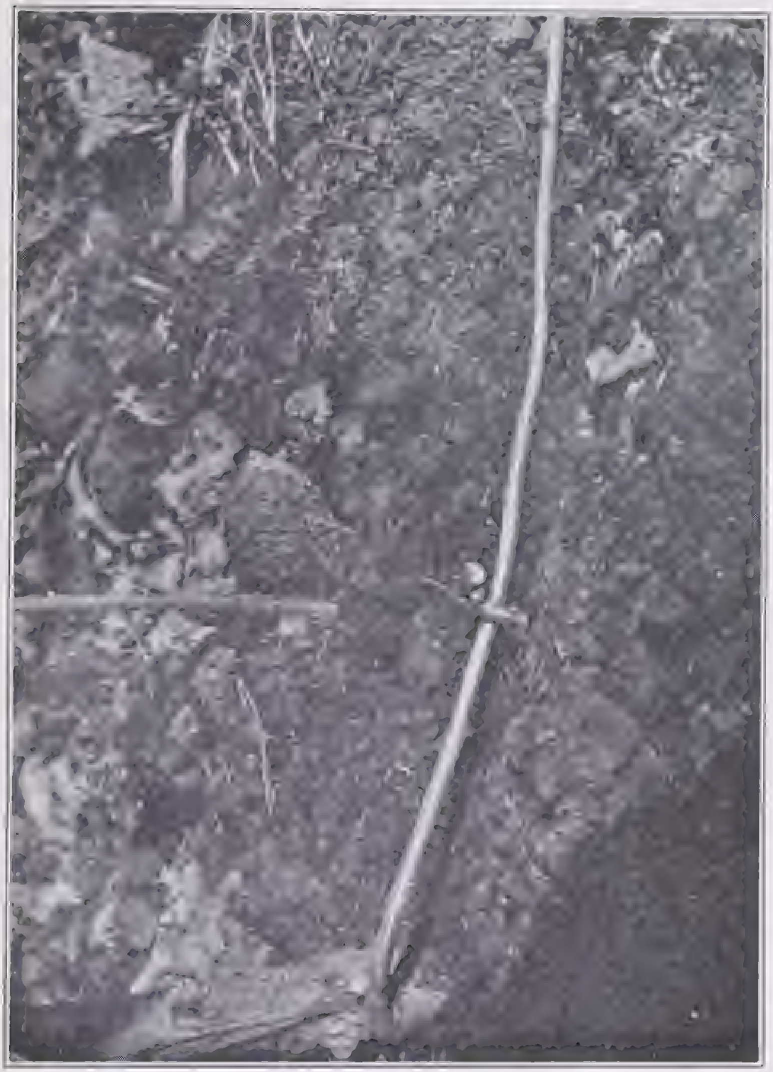

Fig. 2. Shoot laid down for continuous layerage.

Semi-hardwood cuttings made by the breaking off of the current season's growth with an attached heel have also been recommended. In 1923 two thousand such cuttings were tried. These were taken at intervals of two weeks from June 1 to September 1. Only one rooted, and that died before the following spring.

**Continuous layerage.** Continuous layerage is a method more generally in use. The soil is scraped away to a depth of several inches to allow the earth being heaped on later in the season. The shoot to be layered is notched near the point of the attachment to the trunk to allow of easy bending down. After being bent down the shoot is staked to the ground (Fig. 2). As the new shoots begin to grow up from this layered shoot, soil is thrown around the shoots and heaped in until six to eight inches in depth. By having the soil deep, roots will develop both on the layered shoots and on the new growth. If successful, each new shoot will have developed a sufficient root system by early winter to be used in planting new orchards. If not sufficiently rooted, they can be placed in the nursery and by another year will have developed good healthy roots. This class of material has made up the bulk of the nursery stock used in planting filbert orchards up to the present time. The demand for trees was so keen that the nurserymen were not justified in growing trees for another year in the nursery, while the trees grown in the nursery for a year or two were invariably poorly rooted trees that were unsalable the first year. As the production of trees increases, the number of good trees grown for a year in the nursery will undoubtedly increase. These trees will be far more suitable than trees just from the layer.

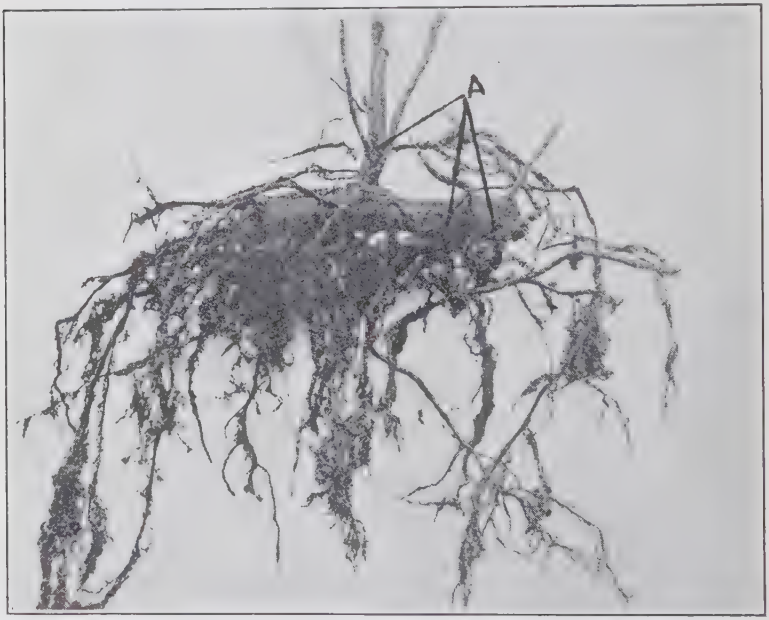

Fig. 3. Layered tree grown in nursery for one year, showing origin of suckers (A). The more of the original layered shoot left the greater the possibility of suckers.

The layered tree as cut away from the original shoot has a piece of the old shoot attached from which suckers will frequently develop vigorously (Fig. 3). By growing in the nursery for a year, strong roots will develop above the old layered wood and this old wood can then be cut away, thus reducing the possibility of suckering (Fig. 4). Without doubt the two-year-old trees grown from well rooted layered stock, either continuous or tip layered, will be found to be the best trees. Suckers will not develop from the roots of the filbert, nor can cuttings be made from roots.

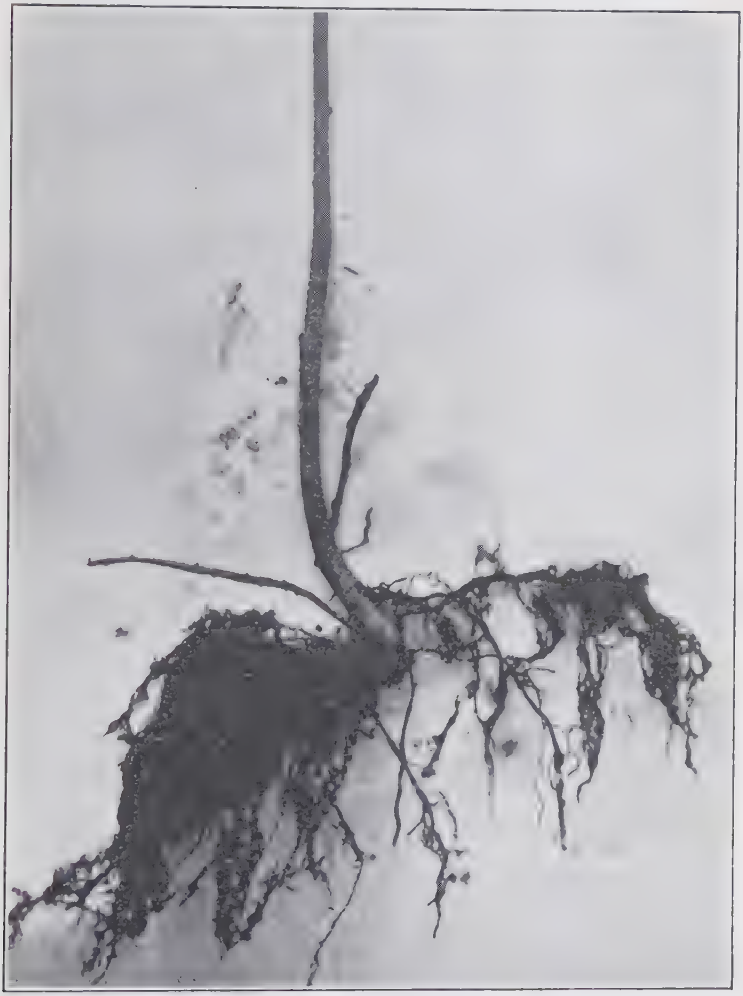

Fig. 4. Tree grown in nursery one year. Old wood cut away. If tree is planted as shallow as possible the suckers must arise near the surface of the ground.

**Tip layerage.** Tip layerage can also be used, but only for a small number the first year. The shoot is bent in a V-shape, burying the lower part of the V from six to eight inches in depth (Fig. 5). Usually from the bend of the layered shoot two or three new shoots will grow. These can be layered the following season, giving a greater number of young trees. For some unknown cause, there is always a small loss of trees through the dying of the layered shoots just above the crook.

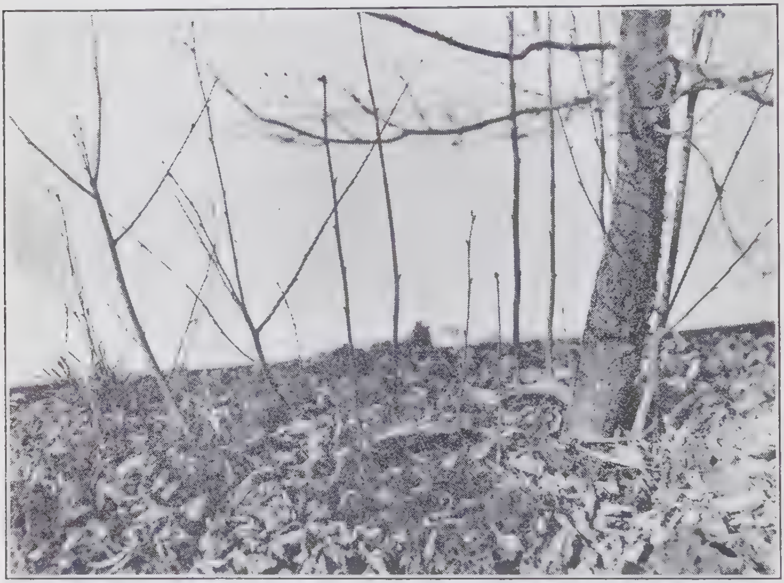

Fig. 5. Method of tip layerage. New shoots growing at the bend that can be used for layerage the following season.

This type of layerage gives a tree with the buds in a regular whorl around the trunk. Those raised from continuous layerage in general develop the buds in a single plane, forming a fan-shaped tree. This fan-shaped tree will in time fill in the open places but will take longer to make a well balanced tree. By cutting bark heavily a top can be developed from a new shoot, on which the buds will be whorled.

**Budding and grafting.** Budding and grafting have been little used until the last few years, while up to the season of 1923 the results had been very erratic. In 1923, possibly due to favorable seasonal conditions, persons using many different methods of grafting and various kinds of wax met with universal success.

Budding and grafting of filberts demand more care than is usual with other fruits. The ordinary cleft graft and the whip graft are commonly used, while the shield bud is used in budding.

Grafting can be done at the usual time for grafting of fruit trees, just before the buds break. The scion wood must be dormant and of the previous year's growth. It should be taken early in February, or earlier, in order for it to be dormant, as the filbert breaks buds very early in the season. Scion wood can be packed in damp moss, sawdust, or similar material, and stored in a cool place.

Budding is performed as with other fruits and at the same time, usually during the month of August. Generally this has not been as successful as grafting. By budding and grafting propagation of filberts can be carried on much more rapidly than with layerage, for one bush or tree will furnish scion wood for a much greater number of trees than can be grown by any form of layerage. This practice necessitates the growing of seedlings. Nuts are stratified in the fall, being stirred frequently throughout the winter and then planted in the nursery in the spring. The nuts ought not to dry out before being stratified, especially with the Corylus colurna (Turkish filbert).

While the seedling rootstock is the best rootstock for such fruits as apples, prunes, pears, etc., it is doubtful if the same is true of filberts. The seedling rootstocks for these other fruits have shown themselves to be so variable that a determined search is being made for some form of rootstock for these fruits that can be propagated successfully by cuttings so as to give a uniform rootstock. In the filbert, layerage gives a uniform root, as it is identical with the parent tree, being part of it from root to top. This will give a greater uniformity in bearing and general vegetative characteristics than any other method of propagation. Weak-growing varieties might be helped by grafting onto vigorous rootstocks. There are no data to warrant the assumption that seedlings of Corylus avellana will be without suckers or less likely to sucker than the standard varieties. Each one will be an individual of itself and behave according to its own characteristics. If grafting on Corylus colurna proves practical, its use may be warranted in producing a comparatively suckerless tree.

*Any filbert tree, grafted or otherwise, is liable to produce suckers unless the rootstock is of a species that naturally does not sucker.*

## PLANTING

**Time of planting.** Early planting should be practiced with all fruit trees. By early planting is meant planting the trees as soon as they can be obtained from the nursery in a dormant condition and when the soil is in fit condition to be worked. Early planting gives the trees a chance to develop their root systems throughout the winter season. A tree so planted will be able, when growth starts in the spring, to furnish plant food in abundance to the growing parts of the tree.

Late planting, on the other hand, will not give time for the roots to make much growth before the buds start in the spring. With a small root system it is impossible for the tree to take in a sufficient supply of raw plant food that can be elaborated by the leaves. Without a sufficient supply of elaborated plant food, growth of either the top or the root will be limited. Late planting should be avoided under all conditions wherever possible, as the trees will more or less stand still throughout the summer.

**Distance apart.** The minimum distance apart for planting of filbert trees is considered to be 20 feet on the poorer soil, while on good land the trees should be placed at least 25 feet apart. In the first plantings made in this state, filberts were planted 12 to 15 feet apart. The large growth of the trees since then has shown this distance to be entirely too close. The tendency at the present time is for greater distances between trees. As data are accumulated as to the full development of mature trees the recommended distance may be increased beyond 25 feet. It does not pay to crowd the trees as they will make a good-sized growth and in the development of the root system will need considerable soil for support.

**Staking the orchard.** The first essential in laying out an orchard is to establish base lines—two or more where the trees are to be planted on the square system, and one where the orchard is to be laid out on the hexagonal system.

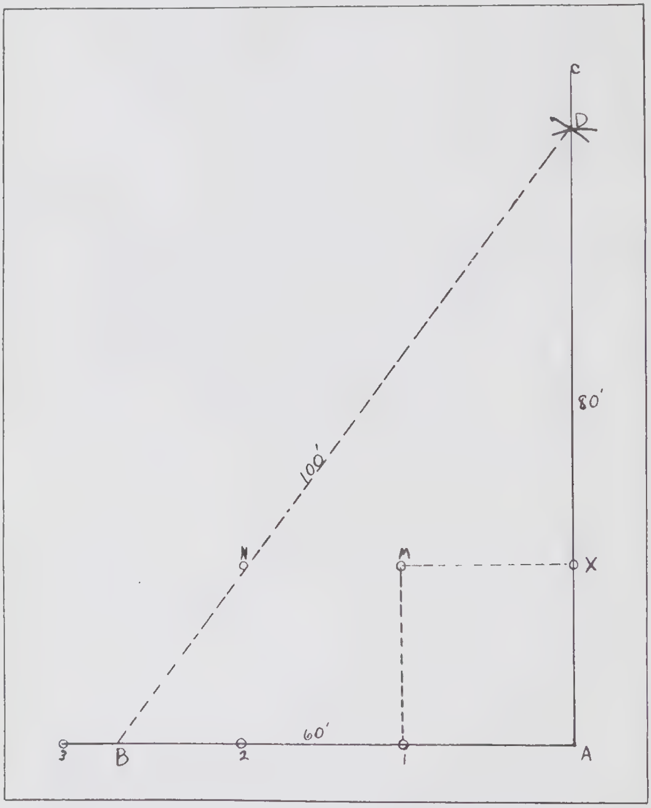

Fig. 6. Laying out the orchard by the square method.

For the square system take one side of the field from which a line can be laid off parallel to the fence or road, as the base line AB (Fig. 6). With a tape or other measure lay out 60 feet on this line AB. Then on the line AC approximately at right angles to base line AB, lay off 80 feet, striking an arc and using A as a pivot point. From point B with a line 100 feet long strike another arc. Where the arc of AD and BD intersect will be the point through which the line AC may be located permanently and at right angles to the base line AB.

It is generally of advantage to lay off another base line at the opposite point of the field from A on the base line AB.

As equipment in laying off by the square system, or by the hexagonal system, one should be provided with a set of wires of the same length as the distance apart that the trees will be set out. These are two wires with one end joined together in a small ring and the free ends fastened to separate rings. After staking off the base line at the intervals desired for the tree, staking of the tract can commence. By placing the wire over stake 1 and stake X, and drawing it taut, a stake can then be placed at point M. Then move the wires over so that the ring can be placed over stake M and stake 2; a stake can then be placed at the center ring at point N. This process can be carried on indefinitely, backward and forward across the field until the field is completely staked out. The wires should be held in the same plane and drawn up to the same degree of tautness. Occasional checking by sighting or by remeasuring the wires will be necessary to straighten out the rows, especially if the field is uneven.

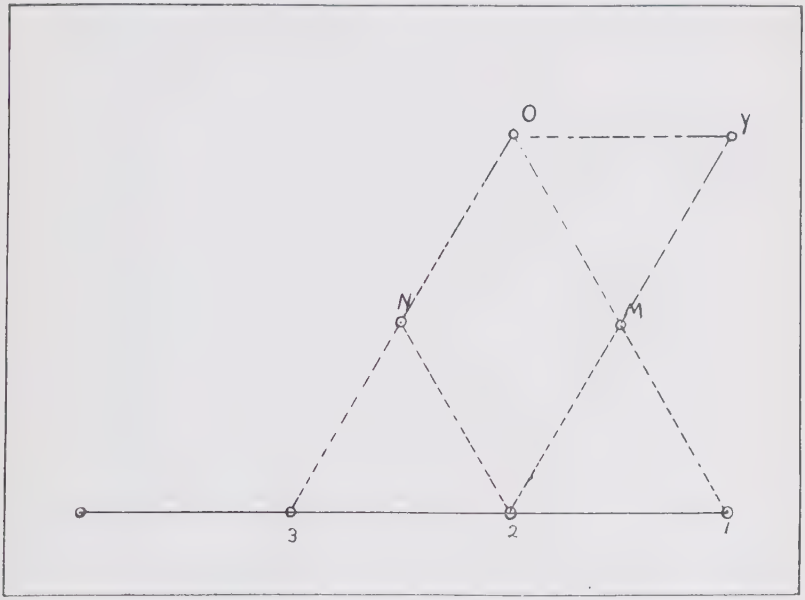

Fig. 7. Laying out the orchard by the hexagonal method.

A long wire with soldered points on it indicating the points at which stakes are to be set is often used.

Other methods of staking out can be used, as by the use of transit or by sighting from two sides of the field with a man to set the stakes at the points desired. On the whole it will probably be found that the use of wire is the quickest and simplest method that can be employed for land not too uneven.

For the triangular or hexagonal system one base line only is needed, spaced at the regular intervals for the planting of the trees. Placing the rings over stakes 1 and 2 (Fig. 7), the wires are drawn tight and a stake is set at M. Then move over until the rings are over stakes 2 and 3; the stake is then placed at N and so on throughout the field. In using this method the rows will each time become shorter so that it will be necessary to fill out the side of the field. By placing one free ring over M in the second row and O in the third row, as illustrated, a stake can be placed at Y so that the third row will be lengthened out to the normal length.

**Using the planting board.** To keep the trees well lined up after the field has been staked out the planting board is of value. This board is three to four feet long with a notch at each end and one in the center. Before digging the hole the board is so placed that the stake showing where the tree will be fills in the center notch. Then place a stake at each end of the board, when the center stake and the board can be taken up. After the hole is dug, place the planting board over the two remaining stakes and with the tree at the center notch, the alignment of the original staking can then be retained.

**Setting the tree.** Digging the hole where the tree is to be planted for any length of time ahead is not advisable. Exposure to the weather will tend to harden the sides of the hole, especially with certain types of soil, so that easy penetration of the soil by the roots cannot be had.

In transferring the tree to the field, avoid allowing the roots to dry out, especially with one-year-old trees, where the roots are fibrous and very tender. They may be kept in a barrel of water or covered with moist earth until finally set out.

Before setting out prune away the remaining parts of the original layered shoots as much as possible. On two-year-old trees remove the old layered shoot and smooth off the broken ends of the main roots.

In planting the tree avoid deep planting, yet set the tree so that the roots will be in moist earth during the dry season. Late planted trees will have to be set deeper than earlier planted trees due to the fact that the root system will not be so completely developed by the time of the dry season. Sift fine earth around the roots and pack with the hand to avoid open air spaces, which allow the roots to dry out. After this, place two or three inches of earth on the roots and tramp down firmly. No damage will come from tramping if sufficient earth is placed on the roots before packing firmly. Above this place loose earth that will form a mulch and prevent evaporation from the firmly packed soil beneath.

## PRUNING

**Pruning young trees.** After setting the tree, the top should be headed back to balance the root system. In transplanting, the roots have been lost to a great extent and thus the water-absorbing capacity of the plant has been materially reduced. Leaving the top the original size will mean that the root system will be unable to provide the proper amount of moisture. Usually a height of eighteen to thirty inches will be found satisfactory. The higher headed trees are not undesirable as picking is from the ground, and up to the present time no spraying has been necessary. Filberts generally have a tendency to spread out with often a drooping habit so that a greater height of the head aids in keeping the limbs away from the ground.

Develop a central leader in the tree so far as practicable, spacing the scaffold limbs five to seven inches apart and distributing them well around the trunk. In most cases pruning the second and following years will consist in thinning out the extra branches and possibly heading back the laterals if they tend to take the lead away from the central leader. A sufficient number of secondary branches will develop along the scaffold limbs without heading them back. Secondary laterals will have to be thinned out rather than forced to grow. Most of the trees in this state have been grown with little or no pruning and have made well shaped trees, but they are usually entirely too thick, which could have been avoided by a consistent thinning out program from the beginning.

**Pruning bearing trees.** Little is definitely known as to the best methods of pruning to follow for bearing trees. In England and other European countries the pruning is very severe, tending to be almost an annual renewing of the wood except for the scaffold limbs.

In this country observation has shown that bearing is sufficiently heavy if the trees are pruned like other fruit trees. It is well known that fruiting wood will not develop in the shade. To avoid this dense shade, prevalent in so many filbert trees, thinning out is advisable in practically all cases.

Filberts are borne laterally and terminally on one-year-old wood. On trees with thick foliage this bearing wood is developed only on the outer side of the tree. Experience with the bearing orchards now to be found in the state has shown that heavy yields can be obtained by a light pruning consisting of a thinning out and, until definite proof can be brought out to warrant any change, this system seems the most advisable.

After the trees reach the age of twelve to fifteen years they frequently show a tendency to slow down in production and wood growth. Heading back will force a heavy new growth that may stimulate bearing for a time. The better practice would be to arrange a good fertilization program and combine this with a vigorous thinning out in pruning. With those plantings that were planted too close, according to the recommendations in the earlier days, taking out part of the trees will be of advantage. Pruning cannot supply plant food and moisture lacking in the soil, but should be used with the aim of preserving vigorous fruiting wood throughout the whole of the tree.

## CULTIVATION

Cultivation should be kept up as with any other fruit. The size of the nut is partly dependent upon having the optimum amount of moisture present in the soil throughout the whole season. Regardless of the fact that the fruit has a hard shell, the size of the fruit is dependent upon moisture to a certain extent as with any other fruit. The moisture in unirrigated sections of Western Oregon can only be maintained by thorough, consistent cultivation throughout the spring and summer.

Cultivation should commence early in the spring by the plowing of the soil. Follow this with some method of pulverizing, such as disking, harrowing, etc., as the needs of the soil indicate. After a dust mulch has been established it needs to be stirred at intervals of ten days to two weeks by some form of harrow to maintain the mulch and so prevent the evaporation of the moisture in the soil. Early cultivation consistently followed throughout the spring is essential in the conservation of moisture. Cultivation will not bring up the moisture from any great depth in the soil; after the top moisture has once escaped it will be impossible to bring it back with any type of cultivation.

**Suckering.** To insure the growth of vigorous trees, and the production of good crops of nuts, suckers should be removed as rapidly as they show. This should be followed up from the start. Remove the earth for a few inches and pull or twist the suckers off at the point of origin. The use of a knife is just as satisfactory, but in either case the suckers must be completely removed since each stub that is left has a great tendency to start a number of suckers (Fig. 8).

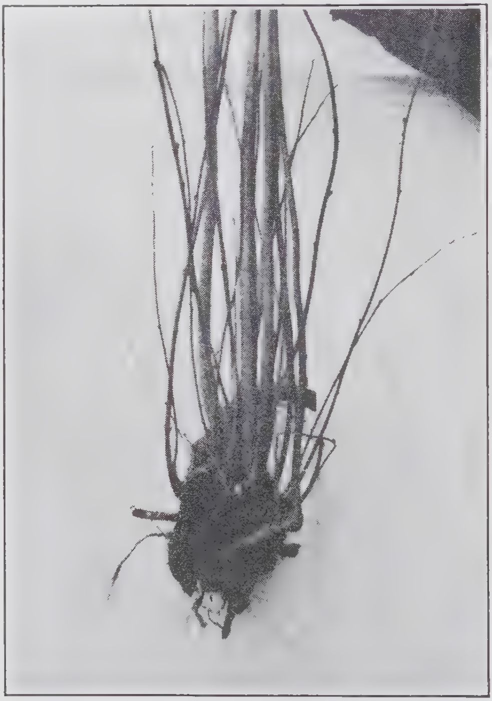

Fig. 8. A clump of suckers growing from a stub where a sucker was incompletely removed in the early life of the tree.

If the suckers are allowed to grow for a year, greater care and much more work will be necessary to stop their growth. If they are persistently removed, the tree will soon lose the habit of suckering and little trouble will follow.

## HARVESTING AND DRYING

In this country filberts are picked from the ground after fully maturing and dropping to the ground. Those that do not free themselves from the husks must be husked out by hand. The nuts are picked at intervals, though the shells will show little discoloration if left to lie on the ground for some time. Even with the hard shell of the filbert the entrance of fungi is not prevented, as nuts with apparently sound shells will show kernels affected by mold. Nuts allowed to lie on the ground for any length of time, especially in rainy weather, will gradually darken, losing the bright, clear color.

After picking up, the nuts need some drying. If nuts are put in heaps the kernels will soon develop a stale taste with considerable growth of mold. No regular drying program is followed, as quantities produced by any one grower are very small. Turning out on the floor in thin layers or similar practices are usually sufficient. Small quantities can be put away without any preliminary drying, but any large amount should be carefully dried before storing to avoid the development of mold and a stale taste.

Where artificial heat is to be used it would seem best not to use a heat higher than that used for walnut, which is from 90° to 100° F. Higher temperature may affect the oil in the kernel as it does with the walnut.

Nuts stored in a dry room will soon become very hard and dry, losing much of the flavor. This flavor can be brought back if the nuts are submitted to a humid atmosphere, as brought out in the bulletin by Hartman.[5] As filberts lose weight so readily and take it on so easily, a standard of moisture content should be established in connection with grades and rules for the grading of the filbert.

No grading rules are in force as yet. It would seem advisable that a definite standard of grading rules be established and followed from the beginning in order to stabilize grades and prices. With the small quantities produced at the present time, the grades are of no importance; but just as soon as the quantity produced becomes large enough for wholesale marketing, definite grades will need to be established in order to stabilize the prices received by the growers.

## BEARING AGE

A few nuts may undoubtedly be found the first or second years. The average planting, however, can not be expected to return a profit on cultural operations before the fifth or sixth years at the earliest.

When filberts reach the maximum production per acre is not known, but there are indications that the tree will increase in production for from ten to twenty years after coming into bearing. Individual trees planted at some distance from adjoining trees will increase the production after that time, but the spacing in most orchards will undoubtedly cause the orchard to reach maximum production at fifteen to twenty-five years of age.

In some years and in a few orchards the yields may run up to 3000 or more pounds per acre, but over a period of years and over a large acreage it would seem to be safer to figure on 1000 pounds per acre as an annual average.

## INSECTS AND DISEASES OF FILBERTS

Neither insects nor diseases are very serious on filberts, so no regular control program has been worked out.

Of the diseases, the bacterial filbert blight is the worst. It is noticeable on young trees by the cankers which frequently girdle the trunk. After the trunk is an inch or so in diameter it is seldom that a canker becomes large enough to girdle the trunk. From that age on, therefore, the disease is of little importance in filbert plantings. It also appears as a blackening and wilting of the young shoots and leaves. The disease is more prevalent during the early part of the summer, or in the spring, and especially in those plants that have been allowed to grow up into a thick, bushy tree or plant.

Control consists in cutting out the infected parts and disinfecting both wound and tools with the following solution:

| | |
|---|---|
| Cyanide of mercury | 1 part by weight |
| Bichloride of mercury | 1 part by weight |
| Water | 500 parts by weight |

*Do not put into a metal container.*

The bacteria are spread by wind, rain, and insects. The canker is cut away to prevent the spread of the disease. After the trees are three to five years old the blight will not do any material damage.

Of the insects, the bud mite, Eriophyes avellanae is most prevalent and noticeable. This insect attacks the buds, which increase to an abnormal size and never open normally. The buds have a reddish color that shows as the bud enlarges and partly unfolds. The mite can be controlled by spraying with lime-sulfur 1 to 12 after the pistils dry up but before the buds begin to open.

Aphids are very numerous during some seasons. Their worst damage seems to be in spreading the blight among the young trees. This is so noticeable at times that a spray of nicotine sulfate 1 to 1,000 should be used to control the aphids. As they feed on the under side of the leaves, care in spraying is necessary in order to reach them.

# PART II. EXPERIMENTAL DATA ON FILBERT POLLINATION

In the first plantings of filberts made in the Pacific Northwest no attention was paid to the matter of cross-pollination as it was considered that filberts were self-fruitful. In 1905, however, A. A. Quarnberg[9] in a letter to Felix Gillette raised the question as to the need of cross-pollination for filberts. In 1919 and 1920 the demand from the growers for accurate information on the pollination needs of filberts led the Experiment Station to start investigations, the results of which are given in this publication.

Apparently under European conditions filberts are self-fruitful, as no necessity for interplanting of varieties is recognized. Quoting E. A. Bunyard:[3] "Judging from large orchards one would assume the commonly grown varieties are quite self-fertile. The Common filbert is notoriously a poor cropper, but this may be due first to the small catkin production and to the fact that in many years the flowers expand before the catkins are shedding their pollen. To remedy this a variety which expands its catkins early should be interplanted. I recommend the La Bergeri." No other reference in literature has been noted as to the pollination requirements of the filbert.

## PROBLEMS OF FILBERT POLLINATION

The outline of the work on the pollination of the filbert contained the following problems:

1. **Self-fertility.*** What varieties can be planted separately and still yield commercial crops?

2. **Self-sterility.** How many of the varieties must be interplanted with other varieties in order to insure commercial crops?

3. **Interfertility.** If any varieties are self-sterile, what varieties are needed to be interplanted for commercial crops?

In the first and second problems, tests were carried out on the varieties commonly found in this section as well as many lesser known varieties. In the third problem the work for the first two years was concerned with the Daviana, Du Chilly, White Aveline, and Barcelona. As investigations continued it became apparent that the Barcelona was the best market variety for Oregon conditions, and during 1922 and 1923 the work was confined to that variety alone.

The commercial growing of filberts has been so recently undertaken in this section that the question of suitable varieties and other related questions were necessarily studied along with the pollination problem. In addition to interfertility of a variety, the following points must be kept in mind.

1. **Blooming date.** The shedding of pollen of the pollenizing variety must coincide with the maturity of the stigmas on the commercial variety.

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*Although the terms fertility and sterility[6] are not as correct as fruitfulness and unfruitfulness, the former terms are employed as being the ones most generally in use.

2. **Production of pollen.** The pollen should be produced abundantly and be vigorous, viable pollen.

3. **Vigor of tree.** A tall, vigorously growing tree is preferred over a low non-vigorous tree.

4. **The commercial value.** The production of a large crop of high class nuts is desirable.

None of the pollenizing varieties so far investigated meets fully the above-mentioned requirements.

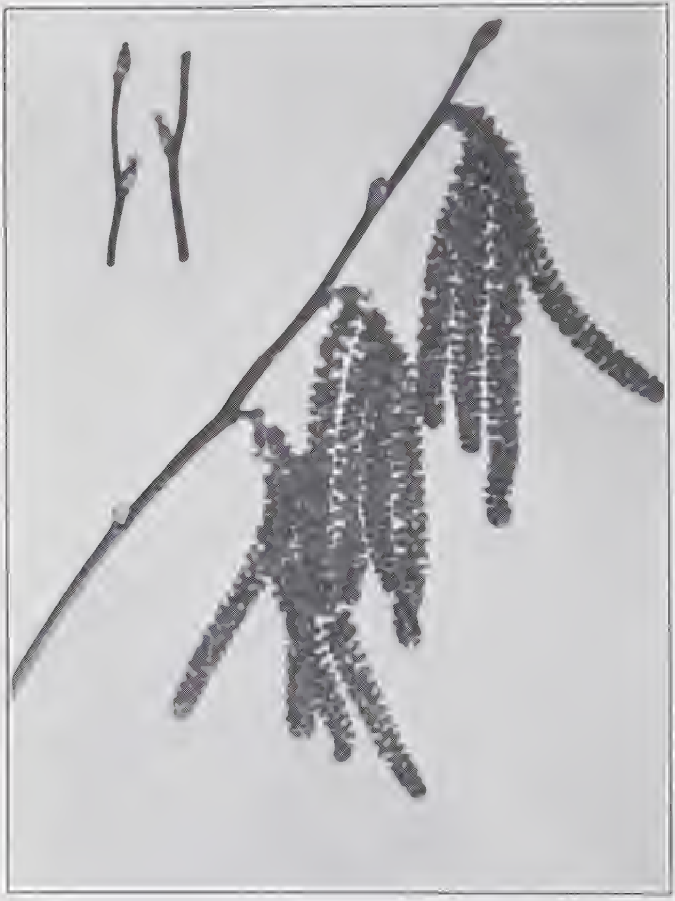

Fig. 9. Male and female catkins in bloom.

## BLOOMING HABITS OF THE FILBERTS

The filbert has monoecious flowers. The female catkin has a very short axis contained within the bud on which are borne six to fifteen pistils that when fully developed extend about three sixteenths of an inch beyond the bud scale. The male catkin has a much longer axis, which elongates to a considerable extent on shedding the pollen (Fig. 9). The blooming time in Western Oregon is from January 1 to March 31, depending upon the season and variety (Fig. 10). With certain varieties, the appearance of the pistils can be noticed much earlier than that; with the Barcelona pistils have been noticed protruding through the bud scales by November 16.

The pollen is blown about by the wind, and bees or other insects are therefore of no importance in cross-pollination. After pollination the pollen tube, according to Benson,[2] makes a short growth into the basal region of the stigma, where the nuclei enter the resting stage and in this condition remain from four to five months. In the meantime, the megaspore completes its development, at which time the pollen tube resumes its growth, and fertilization occurs.

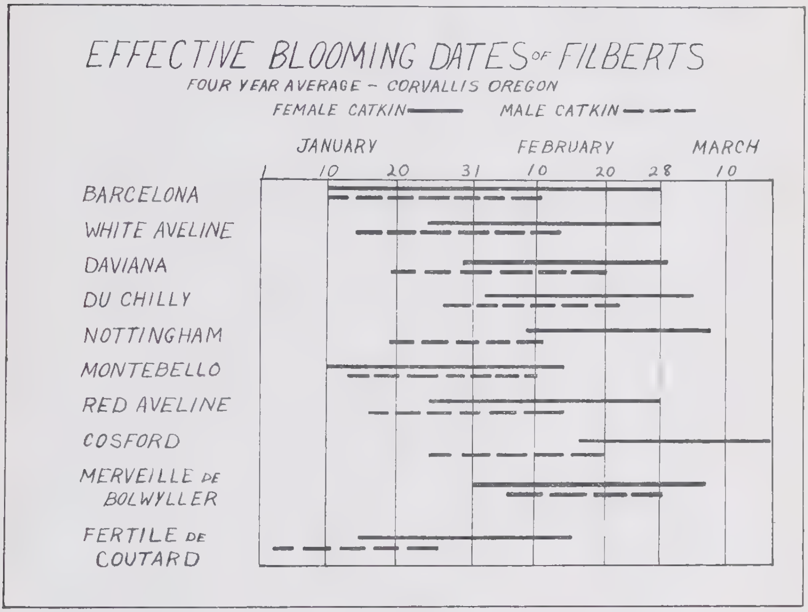

Fig. 10. Effective blooming dates of filberts. With the Barcelona grown as the commercial variety it is essential that the male catkins (commonly called catkins) of the pollenizers shed the bulk of the pollen at the time the female catkins (pistillate flowers) are as nearly as possible at the stage of full development. Not all flowers reach full development at one time.

**Resistance to cold temperatures.** Ordinary frost has no effect on either pistil or pollen. Pistils are the more tender, exposure to temperature of 12 to 15 degrees usually resulting in killing the pistil back to the bud scale. If the growth has just begun the pistil will resume growth after a short time and no damage will be apparent. It has been noticed that pollen was killed at temperatures varying from —10 degrees F. to 3 degrees F. Exposure over a long period of time to temperature above 3 degrees F., as shown by Rimoldi,[8] will result in the killing of part of the pollen. In January 1924, temperatures of 3 degrees F. killed practically all the pollen of certain varieties where the male catkins were nearing maturity.

During the season of 1922 it happened several times that during the night following the application of pollen to the stigmas cold rains set in, so that the following morning the flowers and limbs of the tree would be covered with ice. This generally would not melt until the middle of the following forenoon. No ill effects were noted as compared with those flowers pollinated under apparently more favorable conditions.

**Longevity of pistils.** With the pistils visible beyond the bud scales over a long period of time there was a question as to the receptivity of the stigmas at different times. On January 13, 1922, the pistils showed a maximum development in size of 50 percent on one-fourth of the flowers. The remaining pistils varied from those just protruding to one-half size. As noted on January 26, the pistils were 50 percent developed; by February 9 they had apparently reached the optimum condition, as determined by appearance, and remained so until about February 22. Yet a visit to the orchard on March 7 found many pistils fresh and vigorous looking. This period of full development is lengthened or shortened according as the temperature is cool or warm.

As shown in Table I, either the stigmas are receptive long before they reach full size or the pollen becoming lodged on the rough surface of the pistil remains there in viable condition until the stigmas have become receptive. From a study of the germination of filbert pollen and the slight moisture necessary to germinate the pollen, it may be inferred that the stigmas were receptive over a long period of time, or before they apparently have reached their full development.

TABLE I. EARLY VERSUS LATE POLLINATION ON BARCELONA, 1922

| | Date pollinated | Number of female catkins | Number of clusters of fruit | Percent set |
|---|---|---|---|---|
| | | | | % |
| Barcelona | | | | |
| X White Aveline | 1/13/22 | 1608 | 122 | 7.5 |
| X White Aveline | 1/26/22 | 535 | 157 | 29.3 |
| X White Aveline | 2/ 9/22 | 5249 | 1565 | 29.8 |
| X Daviana | 1/27/22 | 2042 | 358 | 17.5 |
| X Daviana | 2/9-14/2 | 8513 | 2907 | 34.1 |
| X Nottingham | 1/27/22 | 2642 | 57 | 2.1 |
| X Nottingham | 2/15/22 | 907 | 110 | 12.1 |
| X Barcelona | 1/14/22 | 631 | 23 | 3.6 |
| X Barcelona | 1/24/22 | 1677 | 46 | 2.7 |
| X Barcelona | 2/16/22 | 1228 | 24 | 1.9 |

In those sterility tests, however, where pistils were sacked after pollen was being shed by adjoining varieties a larger percentage of apparently self-fruitful flowers resulted even where the pistils were not visible at the time of sacking. For that reason emasculation was carried on before any pollen was shed whatever.

**Pollen production.** Varieties of filberts vary in amount of pollen produced from season to season and according to many factors. Many varieties yield heavily one year, and the following season produce a light set of female and male catkins. Especially is this the case in a planting where fertility in the soil is not well maintained. A change in the cultural practices might increase the average pollen production. Varieties may produce lightly following dry seasons, or when a tree is weakened by disease or other damaging factors. While a variety may yield a large amount of pollen one season, averaging such a variety over a period of years would place it in a lower class so far as pollen production is concerned.

TABLE II. POLLEN PRODUCTION

| Heavy | Medium | Light |
|---|---|---|
| Cosford | Daviana | Purple Aveline |
| White Aveline | Barcelona | Noce Lunghe |
| Red Aveline | D'Alger | |
| Nottingham | Grosse Blanche | |
| Montebello | Kentish Cob | |
| Merveille de Bolwyller | Fertile de Coutard | |
| Princess Royal | Brunswick | |
| Empress Eugene | Du Chilly | |
| Alpha | | |
| Clackamas | | |
| Chaperone | | |

A large part of the varieties classed as heavy pollen producers are light bearers of nuts. It is possible that with proper pollination they might yield more heavily, thus reducing the pollen production in certain years.

## METHODS EMPLOYED

**Emasculation.** Emasculation is simple with the filbert as it consists in cutting off the male catkins. During the seasons of 1920, 1921, and 1923, the female catkins were enclosed in sacks (Fig. 11). As the blooming of the filberts occurs during the rainy season ordinary sacks are of no value. The sacks used were of the toughest texture to be found, dipped in melted paraffin, which rendered them waterproof. If the trees were not subject to excessive winds these sacks would last throughout the season. Where the trees were exposed to constant wind, the sacks would be worn through by continued rubbing against the limbs. In the ordinary plantings it was necessary to leave the sacks on the trees for a period of eight to twelve weeks. Although the main blooming period would be much shorter than that, a few flowers of each kind would be found over that length of time. It was usually necessary to begin the emasculation the latter part of December.

During the season of 1922 no sacks were employed. A total of 63 trees, ranging from 3 to 15 years in age, was used. From these trees all the male catkins were clipped, and the female flowers left exposed to the open. This tract was two hundred yards from the nearest planting, and separated from it by dense timber. The greatest danger from foreign pollen came from the application by hand of the different pollens used. But this was very small as shown by the fact that on a tree with 3500 flowers which was unpollinated 35 nuts resulted, many being blanks.

**Germination of pollen.** Pollen used in the cross-pollination tests was subjected to artificial germination tests in the laboratory. Due to extreme cold weather in the winter of 1919 the pollen used in 1920 was uniformly low in germination. Wherever male catkins were covered by the snow the germination would be excellent, but where exposed the results decreased to the point where all pollen was killed, as happened where the temperature was the lowest.

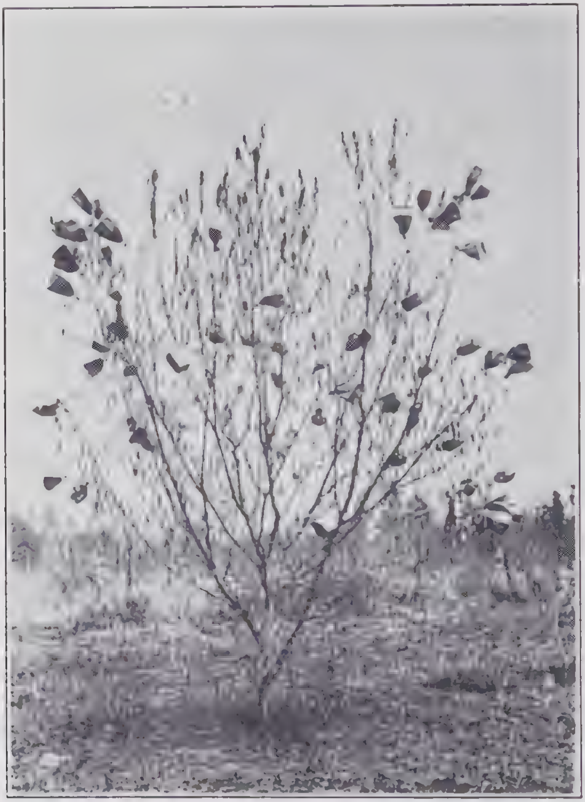

Fig. 11. Female catkins sacked for pollination.

These experiments are not recorded here, but were discarded in the main on account of the lack of vitality of the pollen. In 1921, '22, '23, unless pollen to be used tested 40 percent in germination or better it was discarded and where possible another supply obtained. With the long period over which pollen is being shed this is very easily done with the filberts, insuring viable, vigorous pollen. In a few cases pollen sent in from points in the state arrived at such a time that it was impossible to test it artificially, but resulting figures show that the pollen must have been viable.

Pollen was germinated in media ranging from tap water to 40 percent cane-sugar solution. In the regular hanging droplets in the Van Tiegam cell strengths of 12 to 15 percent gave the best results in most

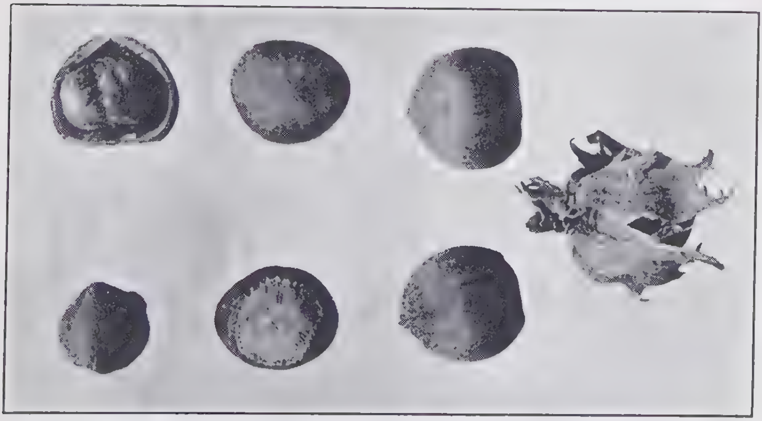

Fig. 12. Barcelona.

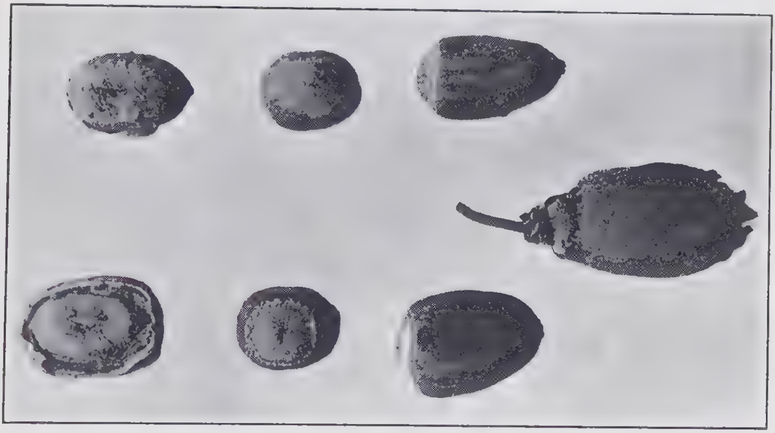

Fig. 13. DuChilly.

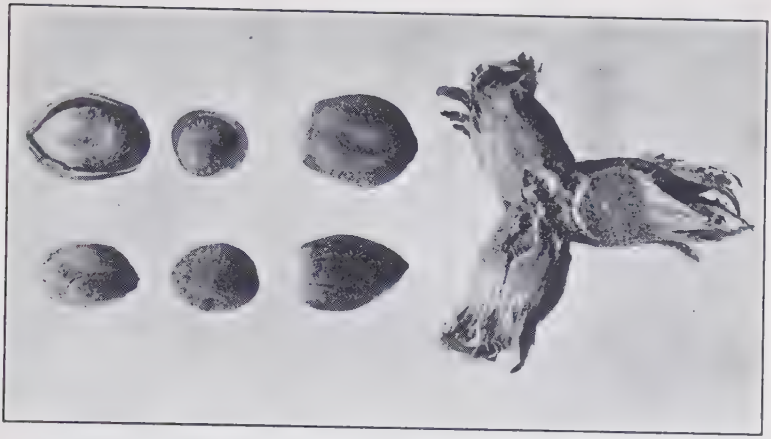

Fig. 14. Nottingham.

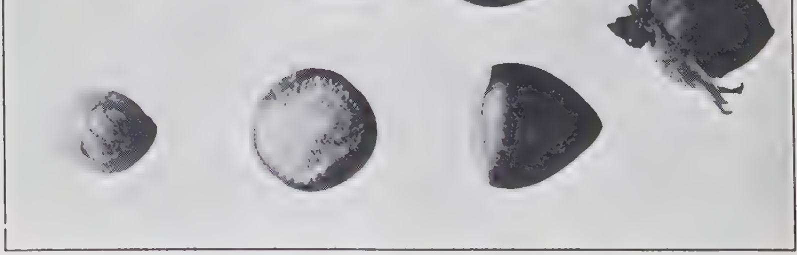

Fig. 15. Merveille de Bolwyller.

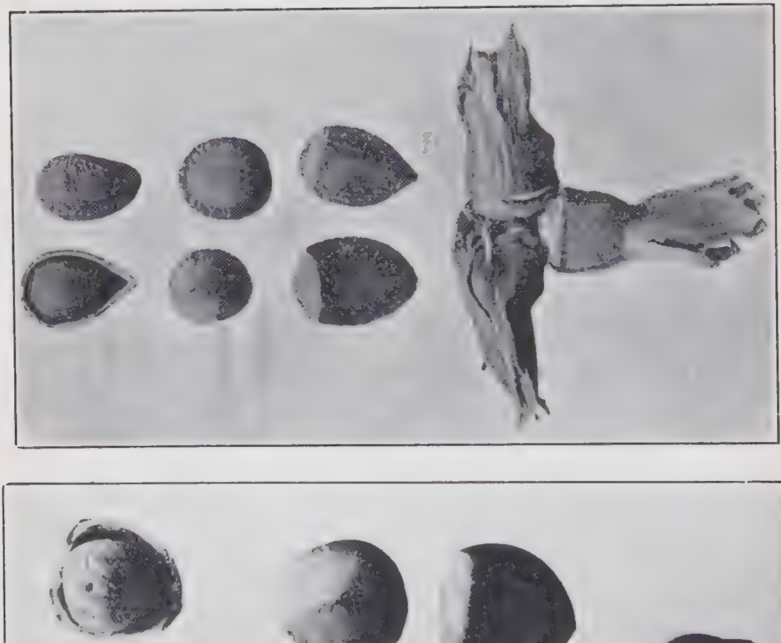

Fig. 16. White Aveline.

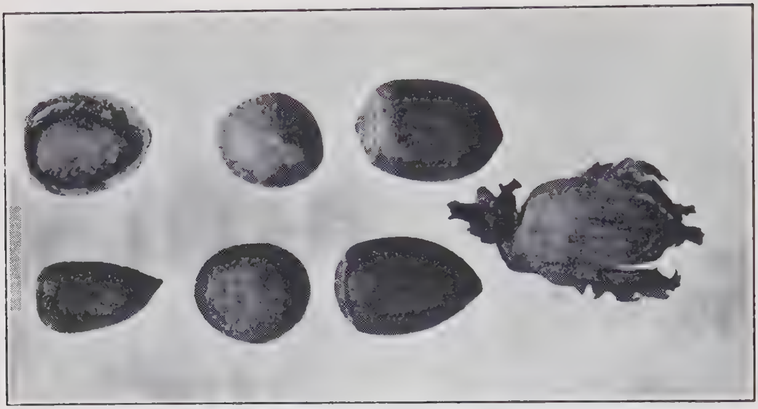

Fig. 17. Daviana.

cases, though results varied at different times of the season. With that strength, considerable bursting of pollen grains and pollen tubes occurred. Best results were obtained by spreading the medium very thinly on the cover slide so that the pollen grain was just covered by the medium. If a thin, broken film could be maintained either of water or sugar solution, a minimum of bursting was noticed. The best germination occurred where the film was so thin that it would barely cover the pollen grain.

In many cases the pollen was tested after the supply was partly used. After intervals of two weeks the viability would not be decreased to exceed 25 percent if it had been left in an open vessel. Pollen corked tightly in vials fermented in 48 to 72 hours.

**Application of pollen.** Pollen was applied with a camel's-hair brush. As the filbert pollen is very light and easily blown about by the wind, it was necessary to carry on the work during those times when the male catkins were wet and pollen not blowing. This was early in the morning or on foggy, rainy days, not at the time usually considered ideal for best pollination purposes. Pollen was so easily obtained that it was applied in such quantities as to be visible to the naked eye, insuring enough viable pollen grains, even with pollen of low germinability.

**Normal set and recording of results.** Most of the work was carried on in orchards bearing a very light crop. It was found that the normal set on those trees meant little or nothing in the comparison with experimental results. A count made on trees bearing well showed that a normal set was from 30 to 50 percent of the female catkins. In recording the results one female catkin with few or many pistils counted as one blossom, and the cluster of nuts resulting was also noted as one fruit. The number of nuts in a cluster is a variety characteristic and is very constant regardless of the kind of pollen applied to the variety, but the number of clusters resulting from cross-pollination is dependent upon the variety from which the pollen came.

Figures were completed for the season by taking a count of the number of clusters resulting, just before the nuts began to fall from the husks.

## POLLINATION OF FILBERT VARIETIES

Table III shows that the varieties tested up to the present time do not show any great tendency toward self-fertility. So far as known the planting of one single variety will always produce a few nuts, so that there is not absolute self-sterility, but it is self-sterility from the commercial standpoint. This is borne out in tests of later years as shown in other tables. It is hoped to find a good commercial variety that is entirely self-fruitful under Oregon conditions.

TABLE III. SELF-STERILITY TESTS, 1921

| Variety | Number of flowers | Number of clusters of fruit | Percent set |
|---|---|---|---|
| | | | % |
| Alpha | 31 | 0 | 0 |
| Barcelona | 249 | 0 | 0 |
| Brunswick | 29 | 0 | 0 |
| Cosford | 44 | 0 | 0 |
| Daviana | 73 | 0 | 0 |
| Du Chilly | 58 | 0 | 0 |
| Du Province | 29 | 0 | 0 |
| Fertile de Coutard | 10 | 0 | 0 |
| Imperial | 28 | 0 | 0 |
| Imperatrice Eugene | 39 | 0 | 0 |
| Kentish Cob | 27 | 0 | 0 |
| Macrocarpa | 28 | 0 | 0 |
| Merveille de Bolwyller | 42 | 1 | 2.3 |
| Montebello | 48 | 0 | 0 |
| Noce Lunghe | 13 | 0 | 0 |
| Nottingham | 31 | 1 | 3.1 |
| Princess Royal | 11 | 0 | 0 |
| Prolific filbert | 15 | 0 | 0 |
| Red Aveline | 37 | 0 | 0 |
| White Aveline | 136 | 0 | 0 |

## CROSS-POLLINATION OF FILBERTS

Since the filbert is self-sterile, interplanting of varieties must be carried out. Table IV shows the results of cross-pollination on the varieties commonly found. In the case of Daviana, the universally light crop borne is primarily due to the bud mite, as the common varieties regularly found interplanted with the Daviana set a good percentage of clusters where healthy flowers are to be found. The percentage of buds affected by the bud mite is regularly so high that a full set of fruit on the remainder of the buds would give but a very light crop.

The White Aveline tree is small, and this fact coupled with the small size of the nut precludes the bearing of large crops even if a large percentage of the blossoms would set fruit.

The Du Chilly bears a fair crop; often a heavy crop is borne one year, followed the next year with a very light crop. For this variety, in addition to the Daviana, the lesser known varieties, as the Chaperone, Clackamas, and Alpha, have been of special value.

With the Barcelona certain varieties have proved very fruitful, while others have been intersterile to a marked degree (Table V). The Barcelona is not a good pollenizer for the other varieties as it uniformly sheds most of its pollen before the pistils on the other varieties are developed. In some seasons when all varieties bloom close together it will be an efficient pollenizer. If a crop is to be expected on any pollenizer recommended to be interplanted with the Barcelona, the Barcelona should not be depended on as a pollenizer but a third variety interplanted.

TABLE IV. CROSS-POLLINATION ON THE DU CHILLY, DAVIANA, AND WHITE AVELINE, 1921

| | Blossoms pollinated | Clusters set | Percent set |
|---|---|---|---|
| Du Chilly | | | % |
| X White Aveline | 103 | 3 | 2.9 |
| X Montebello | 103 | 4 | 3.8 |
| X Wild hazel | 41 | 0 | 0 |
| X Alpha | 175 | 100 | 57.1 |
| X Clackamas | 143 | 79 | 55.2 |
| X Bergeri | 58 | 38 | 65.5 |
| X Merveille de Bolwyller | 139 | 69 | 49.6 |
| X Daviana | 58 | 17 | 29.3 |
| X Barcelona | 35 | 14 | 40. |
| X Cosford | 22 | 6 | 27.2 |
| X Grosse Blanche | 21 | 7 | 33.3 |
| X Nottingham | 51 | 19 | 37.2 |
| X Fertile de Coutard | 28 | 9 | 32.1 |
| X Rouge Ronde | 110 | 10 | 9.0 |
| X Red Aveline | 19 | 1 | 5.2 |
| X Cob | 63 | 3 | 4.7 |
| X Princess Royal | 57 | 31 | 54.3 |
| X Kentish Cob | 82 | 0 | 0 |
| X Empress Eugene | 32 | 0 | 0 |
| X Du Chilly | 72 | 0 | 0 |
| Daviana | | | |
| X White Aveline | 91 | 30 | 32.9 |
| X Montebello | 86 | 18 | 20.9 |
| X D'Alger | 42 | 18 | 42.8 |
| X Grosse Blanche | 36 | 20 | 35.7 |
| X Cosford | 58 | 0 | 0 |
| X Barcelona | 68 | 17 | 25.0 |
| X Kentish Cob | 52 | 15 | 28.8 |
| X Merveille de Bolwyller | 79 | 27 | 34.1 |
| X Nottingham | 58 | 9 | 15.5 |
| X Du Chilly | 26 | 14 | 53.8 |
| X Fertile de Coutrad | 32 | 7 | 21.8 |
| X Grosse Ronde | 47 | 27 | 60.0 |
| X Daviana | 97 | 0 | 0 |
| White Aveline | | | |
| X Daviana | 15 | 2 | 13.3 |
| X Barcelona | 23 | 3 | 13.0 |
| X Red Aveline | 37 | 0 | 0 |
| X White Aveline | 27 | 0 | 0 |
| Nottingham | | | |
| X Du Chilly | 20 | 6 | 30.0 |
| X Daviana | 27 | 10 | 37.0 |
| X Barcelona | 153 | 42 | 27.4 |

TABLE V. CROSS-POLLINATION ON THE BARCELONA

| | 1921 | | 1922 | | 1923 | |
|---|---|---|---|---|---|---|
| | Blossoms pollinated | Percent set | Blossoms pollinated | Percent set | Blossoms pollinated | Percent set |
| Barcelona | | % | | % | | % |
| X Du Chilly | 304 | 36.5 | 1712 | 27.9 | 169 | 24.2 |
| X Red Aveline | 95 | 50.5 | 2638 | 9.6 | ...... | ...... |
| X White Aveline | 224 | 27.0 | 5249 | 29.8 | 110 | 35.4 |
| X Aveline Grosse Ronde | 67 | 35.8 | 1360 | 22.7 | ...... | ...... |
| X Merveille de Bolwyller | 40 | 42.5 | 1479 | 20.0 | 207 | 30.4 |
| X Clackamas | 117 | .8 | ...... | ...... | ...... | ...... |
| X Rouge Ronde | 55 | 0. | 1240 | 6.0 | ...... | ...... |
| X Montebello | 72 | 48.6 | 1418 | 19.3 | ...... | ...... |
| X D'Alger | 193 | 1.0 | 421 | 6.1 | ...... | ...... |
| X Grosse Blanche | 150 | .6 | 332 | 6.9 | ...... | ...... |
| X Cosford | 118 | 61.8 | 4639 | 34.6 | 196 | 44.3 |
| X Daviana | 141 | 29.7 | 8513 | 34.1 | 228 | 31.5 |
| X Fertile de Coutrad | 173 | 2.3 | 1317 | 8.5 | ...... | ...... |
| X Nottingham | 121 | 45.2 | 6131 | 34.3 | 142 | 31.6 |
| X Barcelona | 290 | 6.0 | 1228 | 1.9 | 71 | 0. |
| Unpollinated | 63 | 0. | 3500 | 1. | ...... | ...... |
| X Kentish Cob | ...... | ...... | 1242 | 39.1 | 193 | 34.6 |
| X Imperial Trebizonde | ...... | ...... | 1101 | 21.3 | ...... | ...... |
| X Bergeri | ...... | ...... | 1609 | 21.6 | ...... | ...... |
| X Noce Lunghe | ...... | ...... | 379 | 10.2 | ...... | ...... |
| X Prince Arden | ...... | ...... | 346 | 24.8 | 204 | 28.9 |
| X Brixnut | ...... | ...... | 372 | 2.6 | ...... | ...... |
| X Kruse | ...... | ...... | 1577 | 6.3 | ...... | ...... |
| X Sicily | ...... | ...... | 563 | 18.6 | ...... | ...... |
| X Brunswick | ...... | ...... | 1096 | 18.7 | ...... | ...... |
| X Chaperone | ...... | ...... | 1200 | 10.5 | ...... | ...... |
| X Willamette | ...... | ...... | 361 | 28.5 | ...... | ...... |
| X Purple Aveline | ...... | ...... | 2500 | 12.8 | ...... | ...... |
| X Alpha | ...... | ...... | ...... | ...... | 221 | 34.8 |
| X Wild hazel | ...... | ...... | ...... | ...... | 221 | 0. |
| X Imperatrice Eugene | ...... | ...... | ...... | ...... | 243 | 31.2 |

## CROSS-POLLINATION BETWEEN SPECIES

The question has been brought up as to the feasibility of using the wild hazel (Corylus Californica) in cross-pollination with the filbert. The results of these attempted crosses and those between Corylus avellana and Corylus colurna are given below.

TABLE VI. CROSS-POLLINATION BETWEEN SPECIES OF FILBERTS

| | Blossoms pollinated | Percent set |
|---|---|---|
| Du Chilly | | % |
| X C. Californica | 41 | 0 |
| Barcelona | | |
| X C. Californica | 221 | 0 |
| Du Chilly | | |
| X C. Colurna | 50 | 0 |
| C. Colurna | | |
| X Du Chilly | 11 | 0 |
| X Barcelona | 11 | 0 |
| X Nottingham | 12 | 0 |

It must be remembered that the Corylus Californica and Corylus colurna trees are seedlings and as such the pollen used would show the characteristics of individual trees only, not necessarily of the species. No tests made by growers have shown any beneficial results in setting a crop where wild hazel bushes, shedding pollen, were placed in filbert trees.

Pollen from different districts shows a variation in number of fruits set, but the difference is small. More detailed work on a larger scale might equalize the percentages.

TABLE VII. RESULTS OF CROSS-POLLINATION WITH POLLEN OBTAINED FROM DIFFERENT SOURCES (1923)

| | Blossoms pollinated | Percent set |
|---|---|---|
| Barcelona | | % |
| X Du Chilly (College) | 169 | 24.2 |
| X Du Chilly (Dorris) | 168 | 33.9 |
| X Daviana (College) | 218 | 31.5 |
| X Daviana (Dorris) | 82 | 34.1 |
| X Merveille de Bolwyller (Powell) | 214 | 40.7 |
| X Merveille de Bolwyller (College) | 207 | 30.4 |
| X Merveille de Bolwyller (Quarnberg) | 235 | 33.6 |

The Du Chilly is one of the best pollenizers for the Barcelona. Brunswick, Cob, and Kentish Cob, being synonymous or at most strains of Du Chilly and showing no greater value, should not be propagated or used.

Red Aveline is too much subject to filbert blight and not vigorous enough to warrant its use.

White Aveline (Aveline, Grosse Ronde) is one of the best for cross-pollination.

Merveille de Bolwyller (Geante de Halle), though giving good results, blooms too late. The pollen usually was forced in order to have it ready for the pollination work. In some seasons it would fail.

Rouge Ronde, Grosse Blanche, and D'Alger give the same results as in selfing the Barcelona.

Results with Montebello are inconclusive. Through a mistake in naming trees one season the tests were rendered of no value. Another season the temperature apparently affected the pollen adversely. Actual tests are therefore small. There are possibilities with this variety.

Cosford, though a good pollenizer, blooms so late with its pistillate flowers that it bears a very light crop. No stock is available.

Daviana is recommended as a mid-season pollenizer.

Fertile de Coutard is intersterile with Barcelona.

Due to the better bearing, the Nottingham will undoubtedly replace the Daviana in time as stock becomes available. Just at present but few trees are available, but this will be corrected within a few years.

Imperial Trebizonde, Bergeri, Noce Lunghe, Purple Aveline, and Imperatrice Eugene have no value commercially and little in pollenizing ability to recommend them or to cause them to be used in place of the more common varieties.

Prince Arden, Brixnut, Kruse, Sicily, and Willamette have yet to be proved commercially valuable or else have been discarded.

Chaperone, Clackamas, and Alpha are late bloomers for Barcelona but prove excellent pollenizers and adaptable to combine with Du Chilly.

The wild hazel has failed in every case.

**Planting pollenizers.** The minimum number of pollenizers to use is considered to be eleven percent, or one tree in nine. The simplest method of setting the pollenizers in a planting is to place the pollenizer every third tree in every third row. This places each tree of the commercial variety in contact with a tree of the pollenizing variety. Even if a district should have wind all from one direction during the blooming season, the pollen need not be carried more than two tree spaces.

In the field it has been noted that trees more than fifty feet from the pollenizer yield smaller crops than those closer. Although the pollen is shed abundantly, the female catkin is small and by the time the pollen has traveled any distance it is thinly scattered. Planting pollenizers every third tree in every second row would give added chances for cross-pollination, which might be desirable in the unfavorable seasons.

**Recommended pollenizers for Barcelona.** As the Barcelona has an unusually long blooming season, with the female catkins emerging at intervals throughout the season, more than one variety are recommended as pollenizers. For this purpose the White Aveline, Daviana, and Du Chilly are found acceptable, for not only are they readily obtainable, but they cross-pollenize among themselves, *giving a maximum crop on these varieties*. These varieties begin shedding pollen in the order named so that the flowers of the Barcelona can be supplied with pollen at all times. As soon as the Nottingham trees are available in quantities, they will undoubtedly displace the Daviana due to the heavier bearing of the Nottingham.

As the industry develops, no doubt superior varieties will appear and the varieties now recommended will be displaced by better ones, but these from the standpoint of availability, pollen production, and cross-pollination powers, seem most desirable at the present time.

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# Dry-Farm Crop Rotation Experiments at Moro, Oregon

By

D. E. Stephens

1885

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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# Dry-Farm Crop Rotation Experiments at Moro, Oregon

By

D. E. STEPHENS

## INTRODUCTION

The raising of farm crops in Eastern Oregon, or that portion of the state east of the Cascade Mountains, began about 1870. The first crop following the plowing under of the natural wild grasses was wheat, and the agricultural development of this region has been coincident with the more or less gradual expansion of the wheat acreage. Practically all the land suitable for raising crops without irrigation is now in cultivation, the raising of wheat after summer fallow being the almost universal farm practice.

Many reasons might be stated why farmers of Eastern Oregon should adopt some systematic crop rotation to replace the present practice of growing wheat after a bare fallow. Some of these reasons are:

1. Crop rotation might lessen the drain on soil fertility, especially organic matter and nitrogen, caused by the growing of a single crop continually. Suitable crop rotations, including legumes, or nitrogen-gathering crops, might be used to maintain or increase soil fertility. Green manure crops might also be used to increase the humus content of the soil and improve its physical condition.

2. Crop rotation might aid in the control or elimination of noxious weeds and plant diseases. Certain weeds are troublesome only in certain crops. By changing crops, or using cultivated crops like corn and potatoes, better weed control might be possible. A crop grown continually on the same land is more likely to become injured by disease because of soil infestation by disease organisms peculiar only to that crop.

3. The growing of several crops generally results in a better distribution of farm labor. The production of fall-sown and early and late spring-sown crops, which mature at different times, more evenly distributes farm labor.

4. Crop rotation reduces crop risks and the hazards of low prices. With the production of several crops, there is less likelihood of all of them being low in yield or in price the same year.

5. The total crop output of the farm might be increased if the present large summer-fallowed acreage could be reduced or eliminated by the substitution for the fallow of a crop that will pay for the cost of producing it and not decrease the yields of the following crop as compared with yields obtained after fallow.

6. The labor expense of growing a crop is frequently reduced by suitable crop rotations. Seed-bed preparation for cereals following cultivated crops like corn and potatoes is considerably cheaper because plowing is usually unnecessary.

## DIFFICULTIES OF PRACTISING CROP ROTATION IN EASTERN OREGON

The three chief causes why the farmers of this region have not adopted a more diversified type of farming are: (1) low annual precipitation, which frequently makes annual cropping impracticable; (2) lack of crops as productive as the small grains; and (3) the difficulty of making livestock raising profitable with a scarcity of grazing land for summer pasture. Lack of stock water is also a serious handicap in some locations where grazing land otherwise might be advantageously utilized. Because of limited market, some of the crops other than grains which might be grown cannot always be readily sold.

## LOW PRECIPITATION LIMITS ANNUAL CROPPING

In sections of Eastern Oregon where the average annual precipitation is from nine to fourteen inches, it is frequently necessary to fallow in order to get enough moisture in the soil to grow a crop to maturity. Where the annual precipitation is much less than ten inches, there is rarely a year when sufficient moisture is available to grow a profitable grain crop without the aid of the soil moisture accumulated by a previous season of fallow. Where the average annual precipitation is in excess of twelve inches, the soil in the early spring may frequently contain its maximum field-carrying capacity of soil moisture to a depth of six feet, even when cropped the previous season. With soil moisture content identical in the early spring, however, land fallowed the previous year will generally produce higher yields of grain, especially winter wheat, than land cropped the previous year, due to the plant food made available and stored in the soil during the season of fallow. Table I shows the actual moisture content of the soil at Moro on April 1 for the years 1919 to 1923, inclusive, after fallow and after various crops the previous year.

TABLE I. PERCENTAGES OF MOISTURE, BASED ON DRY WEIGHT, TO A DEPTH OF SIX FEET IN SOIL IN EARLY SPRING AT MORO, OREGON, FOR THE YEARS 1919 TO 1923, INCLUSIVE, AND PRECIPITATION FOR CROP YEARS OF 1919 TO 1923, INCLUSIVE

| Year | After fallow | After peas | After corn | After spring wheat | After winter wheat | Total precipitation for crop year Sept. 1—Aug. 31 |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | *in.* |
| 1919 | 13.8 | 13.7 | 13.4 | 12.8 | 11.1 | 10.72 |
| 1920 | 13.2 | 12.1 | 11.2 | 11.0 | 10.5 | 11.35 |
| 1921 | 13.3 | 14.1 | 12.2 | 13.5 | 13.3 | 12.24 |
| 1922 | 14.6 | 13.8 | 13.2 | 13.2 | 13.0 | 10.32 |
| 1923 | 15.2 | 14.5 | 13.2 | 13.2 | 12.9 | 12.84 |
| Average | 14.0 | 13.8 | 12.4 | 12.7 | 12.2 | 11.5 |

The data in Table I show that on the average, fallowed ground contained only slightly more moisture in the spring than ground on which spring-sown crops had been grown the previous year. After a crop of winter wheat the previous year, the average moisture content of the soil in the spring was 1.8 percent less than that in soil fallowed the previous year.

**Small grains superior to other crops.** For dry lands, the small grains—wheat, barley and oats—have proved superior to all other crops in northern latitudes or in sections with cool climates. On the dry lands of Eastern Oregon, no satisfactory crops have been found that will equal the small grains in seed production. Corn can be grown in many sections of Eastern Oregon, but the returns from this crop on the drier lands are comparatively small and usually not profitable unless utilized for stock or hog feed without the expense of harvesting. In addition to low corn yields, the yields of winter wheat are as a rule considerably reduced after corn as compared with growing winter wheat after fallow.

Alfalfa can be grown anywhere in the eastern part of the state, but the yields from this crop on dry lands, when grown either in cultivated rows or broadcast, have been disappointing. The growing of alfalfa also seems to have a depressing effect in dry-land regions on subsequent grain yields for several years.

Field peas have shown some promise as a substitute for fallow. While the yields obtained are not large, the field pea appears to be sufficiently well adapted to most of Eastern Oregon to justify growing the crop, especially for pasture for hogs or sheep. One objection to it is that from a labor standpoint it competes with wheat to a certain extent. The peas must be sown early in the spring, when the farmer is busy with his plowing operations, and they mature at nearly the same time as winter wheat. The Russian thistle, a widely-disseminated weed in Eastern Oregon, is difficult to control in a field of peas, even when grown in cultivated rows. In Central Oregon field peas when grown on dry land are frequently injured by red spiders.

The growing of field beans would fit into a cropping scheme with wheat better than peas, but the beans are less productive and where tried have not yielded enough to pay production costs.

## LIVESTOCK LIMITED BY SUMMER PASTURES

In any system of diversified agriculture, livestock raising necessarily must be given a prominent place. The raising of much stock on Eastern Oregon dry farms presents many difficulties, the chief of which are the scarcity of grazing lands and stock water for summer pasture and the lack of a perennial hay or forage crop sufficiently productive to warrant its inclusion in a crop rotation with wheat, the present sole cash crop of the Eastern Oregon dry farmer. Few of the dry farms are fortunately situated near available grazing land on which livestock may be pastured during the summer. On most farms the stock must be kept on the farm every day of the year, if kept at all. There are numerous farms with draws or canyons, and some shallow soils suited only for grazing, but the areas of such land are limited and frequently so situated that they cannot be advantageously fenced, thus making it necessary to sow wheat land to a grass or pasture crop if much livestock is kept. No forage plant has yet been found that will compete with winter rye or winter wheat as a pasture or hay crop for most of this region. The replacement of the present one-crop system of raising grain after a bare fallow by a more diversified type of agriculture, including very extensive livestock raising, though theoretically desirable from several aspects, may be attended by so many practical difficulties as to make it of doubtful financial advantage to the dry farmer at the present time. No argument, however, should be necessary to convince the wheat farmer of

Eastern Oregon of the utmost desirability of his keeping enough livestock and poultry to supply family needs in the way of pork, poultry, and dairy products.

## CROP ROTATION INFORMATION NEEDED

Because of the limited number of crops that can be grown profitably on these dry lands, no information is now available on the comparative yields or probable profits from growing various crops in any systematic rotation schemes in actual farm practice. Considerable information, however, has been accumulated at the Branch Experiment Station at Moro on crop yields obtained from a number of different crop rotations. Descriptions of these rotations with the yields obtained are reported in this bulletin, together with a brief discussion of the various crops and of the probable value of different crop rotations for Eastern Oregon. Some of the rotations at Moro have not been in progress long enough to warrant drawing definite conclusions from the results. Others have been in progress for a sufficient length of time to give information of much value and to offer suggestive cropping systems to farmers who desire to change from the present farm practice of growing only wheat to a more diversified type of agriculture.

## CROP ROTATION EXPERIMENTS AT MORO

At the beginning of the experiments at the Moro Branch Station,[1] a series of crop rotations was carefully outlined by H. J. C. Umberger and W. M. Jardine of the Department of Agriculture, and Prof. H. D. Scudder of the Oregon Agricultural Experiment Station. Fifteen rotations were started in 1911; four others were started in 1913; and ten others in 1916 and 1917. The principal questions that it was hoped could be answered from these rotation experiments were:

1. Which of the small grains—winter wheat, spring wheat, oats, or barley—is the most profitable crop to grow after fallow?

2. Can the fallow be partly or entirely eliminated by the substitution of a grain or cultivated crop? If so, what crop?

3. Can a leguminous crop be grown with profit in a rotation with wheat?

4. Will the use of green manure crops to add organic matter and fertility to the soil prove profitable?

The results obtained up to date and a brief discussion of the merits of various crops for inclusion in practical dry-land cropping systems are here presented.

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[1] The Branch Experiment Station at Moro was established in 1909 and is conducted cooperatively by the United States Department of Agriculture through the Office of Cereal Investigations of the Bureau of Plant Industry and the state of Oregon through the Oregon Agricultural Experiment Station. The money to purchase the land and erect the buildings was furnished by Sherman county. The soil on the Station is a typical Columbia River Basin silt loam varying from three to seven feet in depth to the basalt with which it is underlain. The average precipitation for crop years ending August 31 for the period during which the rotation experiments herein reported were conducted, 1912 to 1923, inclusive, was 12.19 inches. The average precipitation for the five-month period, March to July, inclusive, was 3.60 inches for the above twelve-year period.

**Plan of the experiments.** Plots 2 by 8 rods, or an area of one-tenth acre, are used for the rotation experiments. For each rotation as many plots are included as there are years in the rotation, so that data are obtained each year on each phase of the rotation. The plots are grouped in blocks or series of ten, surrounded by roads 16 feet in width. The plots within the series or blocks are separated by alleys 5 feet wide. A general view of the rotation plots at Moro is shown in Fig. 1.

Fig. 1. General view of crop rotation experimental plots at the Sherman County Branch Experiment Station, Moro, Oregon.

**Check plots.** In the rotation area two plots in each series of ten (the third and eighth plots) are check plots uniformly cropped to wheat and fallow. One check plot in each ten is annually cropped, the other being fallowed. When the third plot in any series is cropped, the third plots of the adjacent series are fallowed, and when the eighth plot is in crop, the eighth plots of the adjacent series are fallowed.

During the years 1911 to 1914, Pacific Bluestem spring wheat was grown on the check plots. From 1915 to 1919 Baart spring wheat was grown, and from 1920 to 1922 Turkey winter wheat was grown. The annual and average yields of wheat from these check plots for the years 1912 to 1922 are shown in Table II.

As is shown in Table II, yields for twelve years have been obtained from the check plots for six series. From these check plot yields, which represent the yields obtained from a single one-tenth acre plot from each acre devoted to the rotation experiments, can be obtained an idea of the uniformity of the soil of the rotation area.

For convenience of comparison, the rotations included at Moro have been grouped into five classes: (1) land alternately cropped and fallowed, (2) fallow once in three years, (3) fallow once in four years, (4) no fallow, and (5) rotations involving the use of a green manure crop.

TABLE II. ANNUAL AND AVERAGE ACRE YIELDS OF CHECK PLOTS IN ROTATION EXPERIMENTS AT MORO, OREGON, FOR THE YEARS 1912 TO 1923, INCLUSIVE

| Plot No. | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1918 | 1919 | 1920 | 1921 | 1922 | 1923 | Total | 12-year average | 7-year average 1917-23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* |
| 773 and 778 | 17.6 | 23.0 | 17.8 | 16.1 | 40.4 | 21.2 | 17.5 | 23.0 | 19.7 | 26.0 | 19.0 | 36.3 | 277.6 | 23.1 | 23.2 |
| 783 and 788 | 16.0 | 19.1 | 16.8 | 18.7 | 37.1 | 21.0 | 15.3 | 25.1 | 19.0 | 36.5 | 17.5 | 39.0 | 281.1 | 23.4 | 24.8 |
| 873 and 878 | 11.5 | 23.4 | 16.6 | 18.8 | 33.8 | 23.8 | 16.8 | 21.8 | 18.0 | 29.0 | 17.7 | 38.3 | 269.5 | 22.5 | 23.6 |
| 883 and 888 | 12.6 | 18.5 | 20.0 | 15.8 | 47.8 | 21.5 | 21.3 | 22.0 | 22.7 | 32.5 | 22.5 | 37.7 | 294.9 | 24.6 | 25.7 |
| 973 and 978 | 15.1 | 19.8 | 20.6 | 15.5 | 39.4 | 20.3 | 18.7 | 19.8 | 20.0 | 29.0 | 19.0 | 37.5 | 274.7 | 22.9 | 23.5 |
| 983 and 988 | 13.1 | 19.0 | 19.0 | 16.3 | 39.8 | 20.5 | 17.8 | 23.0 | 21.7 | 39.7 | 19.3 | 40.5 | 289.7 | 24.1 | 26.1 |
| 1073 and 1078 | ...... | ...... | 21.8 | 21.0 | 38.7 | 22.5 | 14.2 | 22.3 | 21.7 | 36.0 | 17.3 | 42.0 | 257.5 | 25.8* | 25.1 |
| 1083 and 1088 | ...... | ...... | 18.6 | 19.3 | 38.2 | 25.3 | 18.0 | 24.8 | 23.7 | 35.8 | 19.5 | 47.3 | 270.5 | 27.1* | 27.8 |
| 1173 and 1178 | ...... | ...... | ...... | ...... | 40.4 | 20.0 | 16.0 | 23.3 | 23.3 | 31.7 | 19.2 | 41.8 | 215.7 | ...... | 25.0 |
| 663 and 668 | ...... | ...... | ...... | ...... | ...... | 17.0 | 14.2 | 22.0 | 18.0 | 33.7 | 17.0 | 37.5 | 159.4 | ...... | 22.8 |
| 863 and 868 | ...... | ...... | ...... | ...... | ...... | 23.8 | 13.5 | 24.0 | 19.8 | 36.3 | 16.5 | 38.3 | 172.2 | ...... | 24.6 |
| 963 and 968 | ...... | ...... | ...... | ...... | ...... | 15.3 | 13.8 | 24.0 | 18.8 | 28.0 | 18.3 | 41.5 | 159.7 | ...... | 22.8 |
| Average | 14.3 | 20.5 | 18.9 | 17.7 | 39.5 | 21.0 | 16.4 | 22.9 | 20.5 | 32.9 | 18.6 | 39.8 | ...... | ...... | ...... |

*Ten-year average.

**Group 1. Land alternately cropped and fallowed.** Yields of four crops after fallow are available for the twelve-year period, 1912 to 1923, inclusive. These are recorded in Table III, which shows the annual and average yields of winter wheat, spring wheat, spring barley, spring oats, and potatoes for this period.

The winter wheat yields are those obtained each year from eight plots of Turkey wheat (Alberta Red, C. I. 2979) on early spring-plowed fallowed ground in the tillage experiments. This ground is adjacent to that used for the rotation experiments. The yields of spring wheat are from the Baart and Pacific Bluestem varieties in the varietal experiments. The spring barley yields are the average yields obtained from two varieties—White Smyrna and Mariout—in the varietal experiment. The oat yields are those obtained from the Sixty-Day variety in the varietal experiment. The potato yields are the average yields obtained from the Early Ohio and Irish Cobbler varieties for the two years 1912 and 1913, and the average yield of five varieties for the years 1914 to 1923, inclusive.

The grain yields recorded in Table III are about the same as those obtained by farmers in the vicinity of Moro on early-plowed and well-kept summer fallow. While the spring-grain varietal trials have not been located on land adjacent to that used for the rotation experiments, the areas for these trials have always been carefully selected for uniformity, and the soil, so far as could be observed, is identical in every way with that of the rotation series. The yields obtained from the same varieties in the varietal experiments after fallow and in the rotation experiments after fallow usually have been in close agreement.

TABLE III. ANNUAL AND AVERAGE YIELDS, IN BUSHELS PER ACRE, OF WINTER AND SPRING WHEAT, SPRING BARLEY, SPRING OATS, AND POTATOES GROWN AFTER FALLOW FOR THE YEARS 1912 TO 1923, INCLUSIVE

| Year | No. 1A Winter wheat after fallow | No. 1B Spring wheat after fallow | No. 1C Spring barley after fallow | No. 1D Spring oats after fallow | No. 1E Potatoes after fallow |
|---|---|---|---|---|---|
| | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* |
| 1912 | 24.0 | 21.4 | 27.5 | 38.6 | 97.6 |
| 1913 | 24.3 | 22.2 | 41.3 | 47.8 | 83.1 |
| 1914 | 28.9 | 23.4 | 39.4 | 65.6 | 91.2 |
| 1915 | 25.9 | 25.3 | 52.1 | 57.2 | 154.5 |
| 1916 | 40.9 | 39.1 | 70.5 | 80.3 | 230.2 |
| 1917 | 22.3 | 18.6 | 41.7 | 37.2 | 100.8 |
| 1918 | 21.3 | 13.9 | 25.9 | 36.9 | 132.0 |
| 1919 | 37.5 | 24.0 | 37.6 | 52.2 | 114.5 |
| 1920 | 31.7 | 20.3 | 34.8 | 35.9 | 147.7 |
| 1921 | 32.9 | 22.5 | 39.7 | 45.6 | 148.5 |
| 1922 | 18.6 | 20.0 | 28.0 | 23.5 | 150.4 |
| 1923 | 39.8 | 35.4 | 56.2 | 80.3 | 184.2 |
| Total | 348.1 | 286.1 | 494.7 | 601.1 | 1634.7 |
| Average | 29.0 | 23.8 | 41.2 | 50.1 | 136.2 |
| Average pounds per acre | 1740.0 | 1428.0 | 1977.6 | 1603.2 | 8172.0 |
| Average annual* seed yield, pounds per acre | 870.0 | 714.0 | 988.8 | 801.6 | --------- |

*When grown after fallow, the crop yield is divided by two to determine the annual yield per acre.

The highest-yielding grain after fallow for the twelve-year period, as shown in Table III, was spring barley, which produced an average acre yield of 41.2 bushels or 1977.6 pounds. The second highest average yield was obtained from winter wheat, 1740 pounds per acre. Spring oats ranked third and spring wheat fourth in actual pounds produced per acre.

To determine the net profit to the farmer, the price per bushel received for these grains and the cost of producing them must be considered. As all grains were produced after a season of fallow, there would be only a slight difference in the cost of producing them. The ten-year average farm price per bushel for wheat from 1913 to 1922, inclusive, in Oregon (Yearbook, 1922) was $1.32; for barley, 88 cents; and for oats, 59 cents. Using these figures and assuming costs of production equal, winter wheat would be the most profitable crop to grow, barley ranking second and oats third. The total acre value of the winter wheat would be $38.28; the barley, $36.25; and the oats, $29.56.

On account of the relatively higher prices paid for wheat during the World War, the above comparison of prices might not be a fair one. According to the Bureau of Crop Estimates of the United States Department of Agriculture, the ten-year average farm price in Oregon from 1907 to 1916 was 89 cents per bushel for wheat, 62 cents per bushel for barley, and 44 cents per bushel for oats. Basing crop values on these figures, the winter wheat was worth $25.81, the spring barley $25.54, and the spring oats $22.04, making the winter wheat only a slightly more profitable crop to grow after fallow than spring barley. On account of the ready sale for wheat and the greater stability in the market price from year to year, winter wheat is undoubtedly the most profitable grain crop to grow after fallow in Eastern Oregon. Another item of considerable importance is that the winter wheat is sown in the fall, when farm work in this section is generally slack, while the planting of any spring crop interferes with the early rush work of spring plowing for fallow.

**Group 2. Fallow once in three years.** In this group are five rotations, as follows:

No. 2 Spring wheat—spring wheat—fallow
No. 3 Spring barley—spring barley—fallow
No. 4 Spring wheat—spring barley—fallow
No. 20 Spring wheat—peas—fallow
No. 25 Winter wheat—spring rye—fallow

Twelve years' results are available for rotations Nos. 2, 3, and 4, eight years' for No. 20, but only six years' for No. 25. In each of these rotations the ground is plowed for fallow in the early spring. In rotations 2, 3, and 4, the seed-bed preparation for the spring grains following spring grain has been spring plowing from four to five inches deep, packing, and one harrowing with a spike-tooth harrow. For the peas in Rotation 20, the ground is fall plowed, disked, and harrowed with a spike-tooth harrow in the spring before planting the peas, which are sown in double rows thirty-five inches apart and cultivated once or twice during the growing season. The spring rye in Rotation 25 is disked in on winter wheat stubble.

The annual and average yields of the crops grown in the five rotations in which two crops are grown followed by a season of fallow, are shown in Table IV. This table also shows the average seed yield per acre in pounds and the average annual seed yield per acre in pounds for all the crops in each rotation.

TABLE IV. ANNUAL AND AVERAGE ACRE YIELDS OF SPRING AND WINTER WHEAT, SPRING BARLEY, SPRING RYE, AND PEAS GROWN IN THREE-YEAR ROTATIONS, WHICH INCLUDE ONE YEAR OF FALLOW, FOR THE YEARS 1912 TO 1923, INCLUSIVE

| | No. 2. Spring wheat—spring wheat—fallow | | No. 3. Spring barley — spring barley fallow | | No. 4. Spring wheat—spring barley—fallow | | No. 20. Spring wheat—peas—fallow | | No. 25. Winter wheat—spring rye—fallow | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Wheat after fallow | Wheat after wheat | Barley after fallow | Barley after barley | Wheat after fallow | Barley after wheat | Wheat after fallow | Peas after wheat | Wheat after fallow | Rye after wheat |
| | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* |
| 1912 | 17.6 | 11.6 | 17.9 | 13.7 | 14.3 | 10.9 | ..... | ..... | ..... | ..... |
| 1913 | 20.2 | 8.3 | 49.4 | 1.0 | 22.1 | 18.3 | ..... | ..... | ..... | ..... |
| 1914 | 20.6 | 12.5 | 27.3 | 21.0 | 18.3 | 15.6 | ..... | ..... | ..... | ..... |
| 1915 | 17.6 | 0 | 21.8 | 6.4 | 14.6 | 9.4 | ..... | ..... | ..... | ..... |
| 1916 | 38.1 | 23.3 | 72.5 | 63.0 | 40.2 | 56.4 | 40.3 | 27.2 | ..... | ..... |
| 1917 | 23.7 | 12.3 | 35.0 | 10.5 | 21.2 | 0. | 21.0 | 1.0 | ..... | ..... |
| 1918 | 15.8 | 11.3 | 24.4 | 12.2 | 18.5 | 13.5 | 16.2 | 6.1 | 19.5 | 11.0 |
| 1919 | 25.2 | 10.7 | 43.0 | 17.0 | 24.2 | 22.5 | 21.7 | 10.3 | 33.2 | 11.0 |
| 1920 | 14.7 | 7.5 | 22.9 | 11.3 | 13.0 | 11.3 | 21.8 | 6.8 | 19.0 | 6.4 |
| 1921 | 24.7 | 17.8 | 33.1 | 31.9 | 24.0 | 34.8 | 25.8 | 9.3 | 36.2 | 14.0 |
| 1922 | 15.7 | 7.5 | 18.7 | 14.1 | 14.7 | 15.2 | 17.2 | 8.5 | 17.0 | 7.9 |
| 1923 | 39.8 | 31.5 | 56.3 | 33.5 | 38.2 | 43.6 | 41.3 | 14.2 | 32.3 | 30.8* |
| Total | 273.7 | 154.3 | 422.3 | 235.6 | 263.3 | 251.5 | 205.3 | 83.4 | 157.2 | 81.1 |
| Average | 22.8 | 12.9 | 35.2 | 19.6 | 21.9 | 20.9 | 25.7 | 10.4 | 26.2 | 13.5 |
| Average pounds per acre | 1368.0 | 774.0 | 1689.6 | 940.8 | 1314.0 | 1003.2 | 1542.0 | 624.0 | 1572.0 | 777.5 |
| Average annual seed yield, pounds per acre | 714.0 | | 876.8 | | 772.4 | | 722.0 | | 783.1 | |

*Spring wheat substituted for rye in 1923.

A comparison of the yields obtained from the five rotations in Group 2 (two crops and a fallow) with those in Group 1 (a grain crop alternated with fallow) shows that higher average annual acre yields were generally produced from grain alternating with fallow than from growing two grain crops and fallowing one year. Spring wheat in Rotation 1B produced an average annual yield of 714 pounds per acre, identically the same annual average yield as in Rotation 2, spring wheat—spring wheat—fallow. It will be noted from Table IV that the spring wheat after spring wheat in Rotation 2 returned profitable yields only in three years out of twelve, 1916, 1921, and 1923, and was a failure in one year, 1915. The cost of producing spring wheat after wheat is considerably greater than the cost of cultivating the fallow. The average yield of wheat after wheat in Rotation 2 was 12.9 bushels per acre, barely enough to pay production costs and interest on land valued at $25.00 an acre.

The annual average acre yield of spring barley after fallow in Rotation 1C was 988.8 lbs. per acre as compared with 876.8 pounds per acre from Rotation 3, with two barley crops and a fallow. In Rotation 3, there were four years—1914, 1916, 1921, and 1923 when the barley after barley produced enough to be profitable. The average yield was 19.6 bushels per acre, while barley after fallow in the same rotation averaged 35.2 bushels per acre.

The results as shown in Table IV emphasize the superiority of barley as a spring-sown crop for Eastern Oregon. In pounds per acre the rotation with two barley crops and a fallow averaged the highest annual seed yield per acre, 876.8 pounds. The second highest was Rotation 25, winter wheat—spring rye—fallow. This rotation has been in progress only six years, and during one of those years, 1923, spring wheat was substituted for spring rye. Spring wheat following the winter wheat would undoubtedly be more desirable in this rotation than spring rye because of the higher yields of spring wheat and because of the difficulty in keeping the wheat free from volunteer rye even after a season of fallow. Rotation 4, spring wheat—spring barley—fallow, averaged 58 pounds per acre more seed annually than Rotation 2, spring wheat—spring wheat—fallow. In Rotation 4, the spring barley after wheat averaged 229.2 pounds per acre more than the spring wheat after wheat.

The wheat yields after fallow in Rotation 20, spring wheat—peas—fallow, are higher than those in Rotations 2 and 4, which are similar rotations without a leguminous crop. High yields of peas in this rotation were obtained in only one year of the eight, the average being 10.4 bushels per acre. With winter wheat substituted for the spring wheat in this rotation, better results would undoubtedly be obtained because winter wheat nearly always outyields spring wheat when grown after fallow.

**Group 3. Fallow once in four years.** In this group are the following eight rotations:

No. 5 Spring wheat—corn—spring wheat—fallow
No. 6 Spring wheat—peas—spring wheat—fallow
No. 15 Spring wheat—corn—oats—fallow
No. 17 Spring wheat—spring barley—fallow—corn
No. 18 Spring wheat—spring barley—manured fallow—corn
No. 22 Winter wheat—peas—winter wheat—fallow
No. 23 Winter wheat—potatoes—winter wheat—fallow
No. 28 Winter wheat—peas—peas—fallow

Twelve years' data are available for two, ten years' data for three, and only six years' data for three of these rotations. Table V shows the annual and average yields for the eight rotations in this group.

Of the rotations with a summer fallow period once in four years, No. 18, spring wheat—spring barley—manured fallow—corn, produced the highest average seed yield, 988.8 pounds per acre annually. This was higher than the seed yield of any rotation in Group 2, with a fallow period once in three years, and equal to the highest in Group 1, Rotation 1C, spring barley—fallow.

Rotation 17, which is the second highest yielding rotation in this group that has been in progress ten years or more, is identical with No. 18, except that barnyard manure at the rate of ten tons per acre is applied in Rotation 18 preceding the fallow year. The wheat yields in both rotations are practically identical, but the corn and barley yields in Rotation 18, where the manure was applied, are enough higher than those obtained from Rotation 17 to indicate a beneficial effect from the barnyard manure in increasing yields when the manure is applied preceding a fallow. It is not certain that the same result would be obtained if a small grain followed the fallow instead of corn. Too heavy applications of barnyard manure may reduce grain yields even after fallow in dry years because of a too heavy drain on soil moisture by the excessive vegetative or straw growth caused by the manure.

Two other rotations of special interest in this group are rotations 5 and 6. No. 5, which is a rotation with a cultivated crop (corn) replacing the fallow one year in four, produced an annual average seed yield of 761.4 pounds per acre, while No. 6, which is a rotation identical with No. 5 except that a leguminous cultivated crop (peas) replaces the fallow one year in four, produced 798 pounds per acre annually. In Rotation 6, the spring wheat after peas averaged 2 bushels per acre more than spring wheat after corn in Rotation 5. The wheat after fallow also yielded slightly higher in Rotation 6 than in Rotation 5.

That Rotation 6 would be a more profitable rotation if winter wheat were substituted for the spring wheat is indicated from the results obtained from Rotation 22, which has been in progress only 6 years. During this period Rotation 22, winter wheat—peas—winter wheat—fallow, produced an average annual seed yield of 883.5 pounds per acre, while during the same six-year period Rotation 6, spring wheat—peas—spring wheat—fallow, averaged only 801.8 pounds per acre annually.

**Group 4. No fallow.** In this group are listed nine rotations:

No. 8 Spring wheat—spring barley—corn
No. 9 Spring wheat—corn—spring barley
No. 10 Spring wheat—spring barley—potatoes
No. 19 Peas continuously
No. 21 Spring wheat—peas
No. 24 Winter wheat—spring rye—peas
No. 26 Winter wheat—corn
No. 27 Winter wheat—peas--peas
No. 29 Corn continuously

Twelve years' results are available for four of these rotations, Nos. 8, 9, 10, and 19. Eight years' results are available for Rotation 21; seven years' for Rotation 26; and six years' for Rotations Nos. 24, 27, and 29. The annual and average yields for these rotations are shown in Table VI.

TABLE V. ANNUAL AND AVERAGE ACRE YIELDS IN BUSHELS OF WINTER AND SPRING WHEAT, BARLEY, OATS, CORN, AND PEAS GROWN IN FOUR-YEAR ROTATIONS, WHICH INCLUDE ONE YEAR OF FALLOW, FOR THE YEARS 1912 TO 1923, INCLUSIVE

| Year | No. 5. Spring wheat—corn—spring wheat—fallow | | | No. 6. Spring wheat—peas—spring wheat—fallow | | | No. 15. Spring wheat—corn—oats—fallow | | | No. 17. Spring wheat—spring barley—fallow—corn | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wheat after fallow | Wheat after corn | Corn after wheat | Wheat after fallow | Wheat after peas | Peas after wheat | Wheat after fallow | Oats after corn | Corn after wheat | Wheat after corn | Barley after wheat | Corn after fallow |
| | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* |
| 1912 | 13.1 | 10.1 | 13.5 | 14.8 | 14.8 | 4.7 | ....... | ....... | ....... | ....... | ....... | ....... |
| 1913 | 19.8 | 12.0 | 0.4 | 21.0 | 20.5 | 10.5 | ....... | ....... | ....... | ....... | ....... | ....... |
| 1914 | 17.6 | 17.5 | 7.3 | 18.7 | 15.1 | 9.8 | 20.1 | 47.8 | 17.5 | 21.6 | 31.3 | 17.0 |
| 1915 | 13.6 | 9.5 | 16.0 | 13.6 | 16.1 | 11.8 | 20.8 | 0. | 15.0 | 23.0 | 15.6 | 17.0 |
| 1916 | 36.3 | 32.1 | 26.8 | 40.8 | 37.5 | 30.8 | 38.8 | 67.5 | 41.6 | 42.9 | 60.2 | 30.0 |
| 1917 | 22.7 | 12.8 | 7.5 | 24.0 | 11.2 | 2.0 | 16.3 | 36.5 | 2.5 | 12.7 | 0. | 0. |
| 1918 | 16.2 | 14.8 | 18.7 | 15.3 | 12.8 | 5.7 | 12.7 | 28.4 | 14.3 | 10.3 | 17.3 | 28.0 |
| 1919 | 22.2 | 24.0 | 10.0 | 24.3 | 19.5 | 12.7 | 22.3 | 35.0 | 4.0 | 25.0 | 18.0 | 21.0 |
| 1920 | 16.7 | 13.5 | 7.4 | 17.2 | 16.2 | 5.0 | 20.7 | 17.2 | 8.3 | 19.5 | 20.8 | 7.9 |
| 1921 | 23.8 | 21.0 | 11.0 | 24.7 | 22.7 | 11.3 | 21.5 | 33.8 | 14.5 | 21.8 | 29.4 | 15.5 |
| 1922 | 14.8 | 12.2 | 12.0 | 17.0 | 16.5 | 8.3 | 13.8 | 21.6 | 14.0 | 15.8 | 18.7 | 24.0 |
| 1923 | 37.2 | 33.7 | 20.7 | 39.5 | 34.8 | 17.2 | 38.0 | 55.0 | 11.7 | 41.2 | 42.7 | 19.7 |
| Total | 254.0 | 213.2 | 151.3 | 270.9 | 237.7 | 129.8 | 225.0 | 342.8 | 143.4 | 233.8 | 254.0 | 180.1 |
| Average | 21.2 | 17.8 | 12.6 | 22.6 | 19.8 | 10.8 | 22.5 | 34.3 | 14.3 | 23.4 | 25.4 | 18.0 |
| Average pounds per acre | 1272.0 | 1068.0 | 705.6 | 1356.0 | 1188.0 | 648.0 | 1350.0 | 1097.6 | 800.8 | 1404.0 | 1219.2 | 1008.0 |
| Average annual seed yield, pounds per acre | ....... | 761.4 | ....... | ....... | 798.0 | ....... | ....... | 812.1 | ....... | ....... | 907.8 | ....... |

| Year | No. 18. Spring wheat—spring barley—manured fallow—corn | | | No. 22. Winter wheat—peas—winter wheat—fallow | | | No. 23. Winter wheat—potatoes—winter wheat—fallow | | | No. 28. Winter wheat—peas—peas—fallow | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wheat after corn | Barley after wheat | Corn after manured fallow | Wheat after fallow | Peas after wheat | Wheat after peas | Wheat after fallow | Potatoes after wheat | Wheat after potatoes | Wheat after fallow | Peas after wheat | Peas after peas |
| | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* |
| 1914 | 22.1 | 30.6 | 17.1 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 1915 | 16.6 | 23.1 | 18.5 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 1916 | 12.0 | 63.1 | 31.1 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 1917 | 20.6 | 18.2 | 19.0 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 1918 | 16.5 | 15.4 | 35.2 | 17.0 | 4.3 | 16.7 | 10.3 | 108.3 | 15.5 | 14.8 | 4.1 | 5.1 |
| 1919 | 25.0 | 27.1 | 10.0 | 28.2 | 8.5 | 28.9 | 22.7 | 55.0 | 22.0 | 35.3 | 11.5 | 16.0 |
| 1920 | 14.7 | 15.0 | 9.7 | 19.7 | 6.8 | 14.5 | 21.1 | 85.8 | 16.5 | 23.0 | 7.8 | 8.0 |
| 1921 | 25.5 | 33.1 | 14.5 | 30.5 | 6.5 | 32.3 | 35.7 | 84.0 | 32.0 | 30.0 | 13.5 | 12.5 |
| 1922 | 12.7 | 22.5 | 24.0 | 17.2 | 9.0 | 15.2 | 17.0 | 111.0 | 18.3 | 16.3 | 9.5 | 8.8 |
| 1923 | 41.8 | 44.2 | 22.1 | 38.8 | 18.0 | 35.0 | 36.0 | 77.3 | 27.3 | 50.0 | 16.3 | 18.2 |
| Total | 237.5 | 292.3 | 201.2 | 157.1 | 53.1 | 142.6 | 142.8 | 521.4 | 131.6 | 169.4 | 62.7 | 68.6 |
| Average | 23.8 | 29.2 | 20.1 | 26.2 | 8.9 | 23.8 | 23.8 | 86.9 | 21.9 | 28.2 | 10.5 | 11.4 |
| Average, pounds per acre | 1428.0 | 1401.6 | 1125.6 | 1572.0 | 534.0 | 1428.0 | 1428.0 | 5214.0 | 1314.0 | 1692.0 | 630.0 | 684.0 |
| Average annual seed yield, pounds per acre | | 988.8 | . | . | 883.5 | ..... | ..... | 914.0 | ..... | ..... | 751.5 | ..... |

TABLE VI. ANNUAL AND AVERAGE ACRE YIELDS IN BUSHELS OF SMALL GRAINS AND CULTIVATED CROPS GROWN IN DIFFERENT ROTATIONS WITH NO FALLOW

| Year | No. 8. Spring wheat—barley—corn | | | No. 9. Spring wheat—corn—barley | | | No. 10. Spring wheat—spring barley—potatoes | | | No. 19. Peas continuously |
|---|---|---|---|---|---|---|---|---|---|---|
| | Wheat after corn | Barley after wheat | Corn after barley | Wheat after barley | Corn after wheat | Barley after corn | Wheat after potatoes | Barley after wheat | Potatoes after barley | |
| | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* |
| 1912 | 10.3 | 15.8 | 29.7 | 18.5 | 28.7 | 21.0 | 15.9 | 17.9 | 122.8 | 14.8 |
| 1913 | 13.4 | 28.5 | 2.5 | 23.0 | 4.3 | 1.6 | 23.0 | 12.3 | 68.0 | 24.0 |
| 1914 | 15.3 | 14.3 | 14.5 | 16.1 | 18.0 | 23.5 | 18.5 | 17.7 | 41.1 | 19.0 |
| 1915 | 8.1 | 23.9 | 19.0 | 9.0 | 20.0 | 29.6 | 16.3 | 16.0 | 73.0 | 9.0 |
| 1916 | 31.7 | 50.6 | 29.9 | 37.9 | 30.8 | 78.5 | 36.3 | 51.3 | 146.6 | 27.4 |
| 1917 | 13.3 | 0. | 21.0 | 7.0 | 22.0 | 16.5 | 13.8 | 0. | 86.0 | 1.9 |
| 1918 | 17.2 | 15.4 | 27.0 | 10.5 | 26.6 | 26.5 | 15.8 | 22.7 | 92.0 | 6.0 |
| 1919 | 23.0 | 23.1 | 7.0 | 22.7 | 6.0 | 35.8 | 23.2 | 26.4 | 35.0 | 13.8 |
| 1920 | 7.5 | 12.9 | 5.6 | 6.7 | 5.1 | 13.8 | 21.3 | 14.8 | 93.8 | 6.1 |
| 1921 | 23.8 | 29.8 | 15.0 | 20.3 | 16.0 | 33.5 | 25.5 | 32.5 | 78.0 | 11.3 |
| 1922 | 12.5 | 14.8 | 13.0 | 12.8 | 13.0 | 16.2 | 16.2 | 17.3 | 110.0 | 8.7 |
| 1923 | 29.0 | 32.7 | 13.1 | 27.8 | 16.0 | 37.5 | 33.5 | 31.9 | 73.3 | 17.9 |
| Total | 205.1 | 261.8 | 197.3 | 212.3 | 206.5 | 334.0 | 259.3 | 260.8 | 1019.6 | 159.9 |
| Average | 17.1 | 21.8 | 16.4 | 17.7 | 17.2 | 27.8 | 21.6 | 21.7 | 84.9 | 13.3 |
| Average, pounds per acre | 1026.0 | 1046.4 | 918.4 | 1062.0 | 963.2 | 1334.4 | 1296.0 | 1041.6 | 5094.0 | 798.0 |
| Average annual seed yield, pounds per acre | ......... | 996.9 | ......... | ......... | 1119.9 | ......... | ......... | 1168.8 | ......... | 798.0 |

| Year | No. 21. Spring wheat—peas | | No. 24. Winter wheat—spring rye—peas | | | No. 26. Winter wheat—corn | | No. 27. Winter wheat—peas—peas | | | No. 29. Corn continuously |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wheat after peas | Peas after wheat | Wheat after peas | Rye after wheat | Peas after rye | Wheat after corn | Corn after wheat | Wheat after peas | Peas after wheat | Peas after peas | |
| | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* |
| 1916 | 43.2 | 27.0 | | | | | | | | | .. |
| 1917 | 22.7 | 2.8 | | | | 7.5 | 10.2 | | | | ........ |
| 1918 | 13.3 | 4.7 | 10.0 | 8.5 | 4.1 | 16.5 | 12.6 | 14.0 | 5.3 | 4.3 | 34.7 |
| 1919 | 24.0 | 9.2 | 22.8 | 9.0 | 9.7 | 25.0 | 6.0 | 22.3 | 12.0 | 17.2 | 18.0 |
| 1920 | 16.7 | 4.8 | 11.0 | 5.4 | 6.2 | 14.2 | 5.1 | 12.0 | 7.8 | 7.3 | 5.7 |
| 1921 | 22.2 | 11.2 | 28.3 | 13.2 | 10.3 | 26.7 | 10.0 | 28.0 | 11.8 | 13.2 | 11.0 |
| 1922 | 16.6 | 8.3 | 12.8 | 7.9 | 7.2 | 11.8 | 14.0 | 11.3 | 8.5 | 6.7 | 14.0 |
| 1923 | 38.7 | 15.0 | 34.5 | 26.7* | 15.0 | 27.3 | 12.3 | 28.0 | 16.0 | 17.7 | 19.7 |
| Total | 197.4 | 83.0 | 119.4 | 70.7 | 52.5 | 129.0 | 71.0 | 115.6 | 61.4 | 66.4 | 103.1 |
| Average | 24.7 | 10.4 | 19.9 | 11.8 | 8.8 | 18.4 | 10.1 | 19.3 | 10.2 | 11.1 | 17.2 |
| Average, pounds per acre | 1482.0 | 624.0 | 1194.0 | 677.7 | 528.0 | 1104.0 | 565.6 | 1158.0 | 612.0 | 666.0 | 963.2 |
| Average annual seed yield pounds per acre | | 1053.0 | | 799.9 | | | 834.8 | .......... | 812.0 | | 963.2 |

*Spring wheat substituted for rye in 1923.

TABLE VII. ANNUAL AND AVERAGE ACRE YIELDS IN BUSHELS OF WINTER AND SPRING WHEAT, BARLEY, OATS, AND CORN GROWN IN DIFFERENT ROTATIONS WITH PEAS OR RYE TURNED UNDER FOR GREEN MANURE

| Year | No. 7. Spring wheat—spring barley—peas turned under—fallow | | No. 11. Spring wheat—spring barley—rye turned under—corn | | | No. 12. Spring wheat—spring barley—peas turned under—corn | | | No. 13. Spring wheat—spring wheat—peas turned under—spring barley | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wheat after fallow and peas turned under | Barley after wheat | Wheat after corn | Barley after wheat | Corn after rye turned under | Wheat after corn | Barley after wheat | Corn after peas turned under | Wheat after barley | Wheat after wheat | Barley after peas turned under |
| | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* |
| 1912 | 14.8 | 15.3 | 12.0 | 17.0 | 27.4 | 12.0 | 13.7 | 31.3 | 9.2 | 15.5 | 18.5 |
| 1913 | 28.0 | 21.9 | 11.2 | 22.5 | 4.0 | 9.5 | 37.5 | 3.8 | 11.6 | 9.5 | 33.7 |
| 1914 | 26.1 | 25.2 | 15.3 | 20.6 | 13.1 | 12.1 | 23.1 | 13.2 | 13.6 | 12.5 | 23.7 |
| 1915 | 18.1 | 29.6 | 8.1 | 24.6 | 22.0 | 7.0 | 13.3 | 23.0 | 8.0 | 9.8 | 21.8 |
| 1916 | 40.3 | 68.1 | 36.9 | 54.8 | 27.8 | 47.5 | 52.1 | 32.8 | 33.3 | 37.1 | 65.0 |
| 1917 | 24.5 | 0. | 9.3 | 0. | 11.5 | 14.7 | 0. | 11.3 | 2.5 | 3.2 | 26.6 |
| 1918 | 21.7 | 18.5 | 15.0 | 17.1 | 33.0 | 12.8 | 15.8 | 39.0 | 9.3 | 12.0 | 22.9 |
| 1919 | 24.0 | 26.1 | 24.0 | 24.0 | 19.2 | 28.2 | 22.3 | 23.6 | 15.7 | 11.2 | 35.2 |
| 1920 | 22.5 | 21.7 | 17.3 | 19.1 | 7.1 | 20.8 | 15.0 | 7.7 | 7.8 | 7.8 | 16.5 |
| 1921 | 30.8 | 35.4 | 22.7 | 32.9 | 14.0 | 22.3 | 32.1 | 13.5 | 20.0 | 16.5 | 34.0 |
| 1922 | 16.5 | 22.5 | 15.2 | 16.4 | 16.0 | 6.7 | 15.8 | 24.0 | 8.5 | 5.2 | 17.5 |
| 1923 | 40.7 | 36.8 | 39.5 | 40.4 | 26.6 | 38.5 | 37.0 | 32.7 | 30.2 | 24.8 | 46.9 |
| Total | 308.0 | 321.1 | 226.5 | 289.4 | 221.7 | 232.1 | 277.7 | 255.9 | 169.7 | 165.1 | 362.3 |
| Average | 25.7 | 26.8 | 18.9 | 24.1 | 18.5 | 19.3 | 23.1 | 21.3 | 14.1 | 13.8 | 30.2 |
| Average, pounds per acre | 1542.0 | 1286.4 | 1134.0 | 1156.8 | 1036.0 | 1158.0 | 1108.8 | 1192.8 | 846.0 | 828.0 | 1449.6 |
| Average annual seed yield, pounds per acre | ......... | 707.1 | ......... | 831.7 | ......... | ......... | 864.9 | ......... | ......... | 780.9 | ......... |

| Year | No. 14. Winter wheat—corn—winter wheat—peas turned under—winter wheat—potatoes | | | | | No. 16. Oats—spring barley—peas turned under—corn | | |
|---|---|---|---|---|---|---|---|---|
| | Wheat after peas turned under | Corn after wheat | Wheat after corn | Potatoes after wheat | Wheat after potatoes | Oats after corn | Barley after oats | Corn after peas turned under |
| | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* | *bu.* |
| 1912 | 14.3 | 10.0 | 12.0 | 122.8 | 15.0 | --------- | --------- | --------- |
| 1913 | 11.4 | 2.0 | 6.6 | 65.8 | 20.0 | --------- | --------- | --------- |
| 1914 | 22.6 | 6.5 | 15.8 | 39.8 | 20.1 | 49.6 | 33.7 | 18.5 |
| 1915 | 13.8 | 14.0 | 16.0 | 60.0 | 15.1 | 33.4 | 17.0 | 19.5 |
| 1916 | 31.3 | 26.0 | 27.7 | 145.0 | 30.4 | 81.5 | 69.8 | 37.0 |
| 1917 | 21.5 | 2.0 | 18.3 | 10.0 | 21.0 | 37.6 | 16.8 | 20.6 |
| 1918 | 11.2 | 15.5 | 15.2 | 50.0 | 7.2 | 34.7 | 12.7 | 27.0 |
| 1919 | 29.0 | 2.0 | 17.2 | 40.0 | 27.3 | 41.0 | 27.5 | 21.0 |
| 1920 | 16.0 | 3.1 | 12.7 | 61.7 | 18.2 | 27.8 | 15.8 | 7.4 |
| 1921 | 32.5 | 9.0 | 23.2 | 89.0 | 23.2 | 46.3 | 41.3 | 14.5 |
| 1922 | 15.3 | 14.0 | 12.8 | 95.0 | 15.5 | 23.7 | 17.5 | 20.0 |
| 1923 | 40.0 | 14.7 | 32.3 | 72.5 | 21.0 | 69.0 | 40.8 | 19.1 |
| Total | 258.9 | 118.8 | 209.8 | 851.6 | 234.0 | 444.6 | 292.9 | 204.6 |
| Average | 21.6 | 9.9 | 17.5 | 70.9 | 19.5 | 44.5 | 29.3 | 20.5 |
| Average, pounds per acre | 1296.0 | 554.4 | 1050.0 | 4254.0 | 1170.0 | 1424.0 | 1406.4 | 1148.0 |
| Average annual seed yield, pounds per acre | --------- | --------- | 814.0 | --------- | --------- | --------- | 994.6 | --------- |

In this group, with no fallow included, are found several of the best crop rotations tried at the Moro Branch Station from the standpoint of highest average annual seed production per acre.

The highest yield was obtained from Rotation 10, spring wheat—spring barley—potatoes. In computing the average annual seed yield in this rotation, the yields of the potatoes are not considered. The yield of wheat in this rotation was higher than that obtained from rotations 8 and 9, where corn was used as the cultivated crop. A fair average yield of potatoes, 84.9 bushels per acre, was obtained. The potatoes, however, when grown after grain on dry lands, are usually small, of poor quality, and contain a high percentage of unmarketable tubers. The yield recorded in this rotation is the total and not the marketable yield. Considerably higher yields and better quality of potatoes can be grown after a season of fallow. Potatoes in Rotation 1E yielded 136.2 bushels per acre for the same period, with a much higher percentage of marketable tubers. Even if the yield and quality of the potatoes justified it, the crop could not be grown on an extensive scale on the dry lands of Eastern Oregon because of the danger of over-production and low prices.

In rotations 8 and 9 the three crops, wheat, barley, and corn, are used, but in a different sequence. Rotation 9, where the barley followed the corn instead of wheat, gave the highest average yield for each of the three crops, the greatest increase being in the average yield of the barley, which produced 1,334 pounds of grain after corn as against 1,026 pounds of wheat after corn in Rotation 8. The average annual seed yields from these two rotations are higher than those obtained from any in Group 1, where grain was grown after fallow, the common farm practice in Eastern Oregon.

Notwithstanding occasional low annual acre yields, the average yields of the wheat and barley in these two rotations are high enough to warrant the statement that both of them would prove profitable for farmers who cared to combine grain farming with livestock raising.

Somewhat higher average yields might be obtained from these two rotations by the substitution of winter wheat for spring wheat. The yields of winter wheat, however, in Rotations 26 and 27 in this group indicate that this substitution might not greatly increase the yields. Frequently spring wheat after any crop the previous year will yield nearly as much as winter wheat, mainly because of the difficulty in securing good stands of winter wheat after either a cultivated or a grain crop.

**Group 5. Rotations with green manure crops.** The following six rotations are carried on at the Moro Branch Station to determine the effect on yield of turning under green manure crops.

No. 7 Spring wheat—spring barley—peas turned under—fallow
No. 11 Spring wheat—spring barley—rye turned under—corn
No. 12 Spring wheat—spring barley—peas turned under—corn
No. 13 Spring wheat—spring wheat—peas turned under—spring barley
No. 14 Winter wheat—corn—winter wheat—peas turned under—winter wheat—potatoes
No. 16 Oats—spring barley—peas turned under—corn

In this group are five 4-year rotations, all including spring-sown crops, and one 6-year rotation which includes winter wheat. Each of these rotations, except No. 16, has been in progress since 1912. Rotation 16 was begun in 1914.

The rye for green manure in Rotation 11 is sown in the fall on disked barley stubble and turned under early in June when the crop is about 50 percent headed. The field peas are sown in early spring on disked grain stubble and turned under about the middle of June when in blossom. No crop is grown the year the green manure is turned under, but the land is left fallow, double disked and not plowed as a preparation for the grain crop following the green manure. When corn follows the green-manure crop, the land is plowed shallow in the spring and harrowed as a seed-bed preparation.

In Rotation 7 the green manure is followed by a year of fallow. In Rotation 13 the green manure is followed by spring barley and in Rotation 14 by winter wheat. In all other rotations of this group, the green manure is followed by corn.

The results obtained in these rotations involving the use of green-manure crops, are given in Table VII.

A comparison of the results obtained with the rotations included in Group 5, where a crop is grown for turning under for green manure, with the results from the other rotations in the preceding groups, conclusively shows that the use of green manure would not be advisable as a farm practice because of the failure of this method to increase yields sufficiently to justify the expense of growing the green manure crop. Winter wheat and spring barley produced lower yields following a green-manure crop than when grown after fallow.

Rotation 14 included in this group, is the only one in the whole series of rotations at Moro for which twelve years' data are available for winter wheat grown after a crop the previous year. This rotation includes winter wheat after peas turned under, after corn, and after potatoes. The average yields obtained from the winter wheat after corn and after potatoes were slightly less than the average yields of spring wheat after corn and after potatoes in most other rotations. The comparatively low yields of winter wheat in Rotation 14 may be partly due to the unfavorable location of the rotation for winter wheat, a north slope, and also the failure in several seasons to get good stands of winter wheat in this rotation.

**Summary of rotation yields by groups.** The data given in Tables III to VII, inclusive, are summarized in Table VIII, which shows the rotations arranged in groups as in previous tables, with average yield in pounds per acre for each crop and for each rotation. The average yields are for the twelve-year period, 1912 to 1923, inclusive, unless otherwise stated. Where potatoes are grown the yields are not included in the average seed yield for the rotation.

In comparing the average annual acre yields with those obtained from alternating winter wheat and fallow, which is the established cropping system on practically all the dry lands of Eastern Oregon, it will be seen from Table VIII that the following rotations exceeded the winter wheat-fallow rotation in average annual seed yields per acre.

No. 1C Spring barley—fallow
No. 3 Spring barley—spring barley—fallow
No. 17 Spring wheat—barley—fallow—corn
No. 18 Spring wheat—barley—manured fallow—corn
No. 22 Winter wheat—peas—winter wheat—fallow
No. 23 Winter wheat—potatoes—winter wheat—fallow
No. 8 Spring wheat—barley—corn
No. 9 Spring wheat—corn—barley
No. 10 Spring wheat—barley—potatoes
No. 21 Spring wheat—peas
No. 29 Corn continuously
No. 16 Oats—barley—peas turned under—corn

Of the rotations which have been in progress for the twelve-year periods, Nos. 1C, 8, 9, 10, and 21 have produced the highest annual average yield of grain. No. 10, however, includes potatoes as a fallow substitute, and as the yield and quality of the potatoes would not justify growing them, the same rotation with a fallow instead of the potatoes would be a more profitable one.

The yield of spring barley after fallow in Rotation 1C has exceeded the yield of winter wheat after fallow in pounds per acre. The slightly higher price paid for winter wheat, however, would probably make the winter wheat after fallow the more profitable rotation of the two.

Rotations 8 and 9, in which the crops spring wheat, spring barley, and corn are used, both produced higher average yields of seed per acre than the growing of winter wheat after fallow. From the standpoint of yield, crop utilization and salability, these two rotations are outstanding, and seem to offer more promise in the way of successful crop diversification in Eastern Oregon than any of the other rotations tried. Both these rotations are admirably adapted to a combination system of grain and livestock raising, and the net profit obtained from them as compared with growing wheat after fallow would largely depend upon whether the livestock could be made to return a profit. The corn yields in both rotations are low, about seventeen bushels of grain per acre; but if the corn were utilized for pasture or silage, it might prove profitable, especially for farmers otherwise favorably situated as regards grazing land for livestock. The barley in this rotation could be utilized for stock or hog feed, leaving wheat as the sole cash crop.

The results obtained from Rotation 21 (spring wheat—peas), which has been in progress only eight years, indicate the possibility of the successful introduction of this leguminous crop as a fallow substitute. If the price of peas were computed at their feed value, they would not prove quite so profitable as corn, but due to the total low production because of the restricted areas in which peas can be profitably grown, the market price per pound for peas is always considerably more than that of corn. Peas, too, have the advantage of being a leguminous crop, which in any rotation is generally considered highly essential from the standpoint of soil fertility.

TABLE VIII. SUMMARY OF YIELDS OBTAINED IN ROTATION EXPERIMENTS AT MORO, OREGON, SHOWING ROTATIONS ARRANGED BY GROUPS, AND THE AVERAGE YIELD IN POUNDS PER ACRE OF EACH CROP AND OF EACH ROTATION

| Rotation No. | | Average annual yield per acre for | |
|---|---|---|---|
| | | Crop | Rotation |
| | | *lbs.* | *lbs.* |
| | **Group 1. Fallow and cropped alternately** | | |
| 1A | Winter wheat—fallow | 1740.0 | 870.0 |
| 1B | Spring wheat—fallow | 1428.0 | 714.0 |
| 1C | Spring barley—fallow | 1977.6 | 988.8 |
| 1D | Spring oats—fallow | 1603.2 | 801.6 |
| 1E | Potatoes—fallow | 8172.0 | 4086.0 |
| | **Group 2. Fallow once in three years** | | |
| 2 | Spring wheat—spring wheat—fallow | | |
| | Spring wheat after fallow | 1368.0 | ......... |
| | Spring wheat after wheat | 774.0 | 714.0 |
| 3 | Spring barley—spring barley—fallow | | |
| | Barley after fallow | 1689.6 | ......... |
| | Barley after barley | 940.8 | 876.8 |
| 4 | Spring wheat—spring barley—fallow | | |
| | Wheat after fallow | 1314.0 | ......... |
| | Barley after wheat | 1003.2 | 772.4 |
| 20 | Spring wheat—peas—fallow (8 yrs.) | | |
| | Wheat after fallow | 1542.0 | ......... |
| | Peas after wheat | 624.0 | 722.0 |
| 25 | Winter wheat—spring rye—fallow (6 yrs.) | | |
| | Winter wheat after fallow | 1572.0 | ......... |
| | Rye after wheat | 777.5 | 783.1 |
| | **Group 3. Fallow once in four years** | | |
| 5 | Spring wheat—corn—spring wheat—fallow | | |
| | Wheat after fallow | 1272.0 | ......... |
| | Wheat after corn | 1068.0 | ......... |
| | Corn after wheat | 705.6 | 761.4 |
| 6 | Spring wheat—peas—spring wheat—fallow | | |
| | Wheat after fallow | 1356.0 | ......... |
| | Wheat after peas | 1188.0 | ......... |
| | Peas after wheat | 648.0 | 798.0 |
| 15 | Spring wheat—corn—oats—fallow (10 yrs.) | | |
| | Wheat after fallow | 1350.0 | ......... |
| | Oats after corn | 1097.6 | ......... |
| | Corn after wheat | 800.8 | 812.1 |
| 17 | Spring wheat—barley—fallow—corn (10 yrs.) | | |
| | Wheat after corn | 1404.0 | ......... |
| | Barley after wheat | 1219.2 | ......... |
| | Corn after fallow | 1008.0 | 907.8 |
| 18 | Spring wheat—barley—manured fallow—corn (10 yrs.) | | |
| | Wheat after corn | 1428.0 | ......... |
| | Barley after wheat | 1401.6 | ......... |
| | Corn after manured fallow | 1125.6 | 988.8 |
| 22 | Winter wheat—peas—winter wheat—fallow (6 yrs.) | | |
| | Wheat after fallow | 1572.0 | ......... |
| | Peas after wheat | 534.0 | ......... |
| | Wheat after peas | 1428.0 | 883.5 |
| 23 | Winter wheat—potatoes—winter wheat—fallow (6 yrs.) | | |
| | Wheat after fallow | 1428.0 | ......... |
| | Wheat after potatoes | 1314.0 | ......... |
| | Potatoes after wheat | 5214.0 | 914.0* |
| 28 | Winter wheat—peas—peas—fallow (6 yrs.) | | |
| | Wheat after fallow | 1692.0 | ......... |
| | Peas after wheat | 630.0 | ......... |
| | Peas after peas | 684.0 | 751.5 |

*Yield of potatoes not included.

### TABLE VIII (CONCLUDED). SUMMARY OF YIELDS IN ROTATION EXPERIMENTS

| Rotation No. | | Average annual yield per acre for Crop | Rotation |
|---|---|---|---|
| | | *lbs.* | *lbs.* |
| | **Group 4. No fallow** | | |
| 8 | Spring wheat—barley—corn | | |
| | Wheat after corn | 1026.0 | |
| | Barley after wheat | 1046.4 | |
| | Corn after barley | 918.4 | 996.9 |
| 9 | Spring wheat—corn—barley | | |
| | Wheat after barley | 1062.0 | |
| | Corn after wheat | 963.2 | |
| | Barley after corn | 1334.4 | 1119.9 |
| 10 | Spring wheat—spring barley—potatoes | | |
| | Wheat after potatoes | 1296.0 | |
| | Barley after wheat | 1041.6 | |
| | Potatoes after barley | 5094.0 | 1168.8* |
| 19 | Peas continuously | | |
| | Peas after peas | 798.0 | 798.0 |
| 21 | Spring wheat—peas (8 yrs.) | | |
| | Wheat after peas | 1482.0 | |
| | Peas after wheat | 624.0 | 1053.0 |
| 24 | Winter wheat—spring rye—peas (6 yrs.) | | |
| | Wheat after peas | 1194.0 | |
| | Rye after wheat | 677.7 | |
| | Peas after rye | 528.0 | 799.9 |
| 26 | Winter wheat—corn (7 yrs.) | | |
| | Wheat after corn | 1104.0 | |
| | Corn after wheat | 565.6 | 834.8 |
| 27 | Winter wheat—peas—peas (6 yrs.) | | |
| | Wheat after peas | 1158.0 | |
| | Peas after wheat | 612.0 | |
| | Peas after peas | 666.0 | 812.0 |
| 29 | Corn continuously (6 yrs.) | 963.2 | 963.2 |
| | **Group 5. The use of green manure crops** | | |
| 7 | Spring wheat—spring barley—peas turned under—fallow | | |
| | Wheat after fallow and peas turned under | 1542.0 | |
| | Barley after wheat | 1286.4 | 707.1 |
| 11 | Spring wheat—spring barley—rye turned under—corn | | |
| | Wheat after corn | 1134.0 | |
| | Barley after wheat | 1156.8 | |
| | Corn after rye turned under | 1036.0 | 831.7 |
| 12 | Spring wheat—spring barley—peas turned under—corn | | |
| | Wheat after corn | 1158.0 | |
| | Barley after wheat | 1108.8 | |
| | Corn after peas turned under | 1192.8 | 864.9 |
| 13 | Spring wheat—spring wheat—peas turned under—spring barley | | |
| | Wheat after barley | 846.0 | |
| | Wheat after wheat | 828.0 | |
| | Barley after peas turned under | 1449.6 | 780.9 |
| 14 | Winter wheat—corn—winter wheat—peas turned under—winter wheat—potatoes | | |
| | Wheat after peas turned under | 1296.0 | |
| | Corn after wheat | 554.4 | |
| | Wheat after corn | 1050.0 | |
| | Potatoes after wheat | 4254.0 | |
| | Wheat after potatoes | 1170.0 | 814.0* |
| 16 | Spring oats—spring barley—peas turned under—corn (10 yrs.) | | |
| | Oats after corn | 1424.0 | |
| | Barley after oats | 1406.4 | |
| | Corn after peas turned under | 1148.0 | 994.6 |

*Yield of potatoes not included.

## CROP VALUES AND PRODUCTION COSTS

In order to determine the value of any particular rotation, cost of production and the values of the crops produced necessarily must be considered. In order to compare the value of the crops in the different rotations, the following prices for the various crops have been assumed:

| | |
|---|---|
| Wheat | 1½c per lb. |
| Oats, barley, and corn | 1¼c per lb. |
| Peas | 2½c per lb. |
| Potatoes | 1c per lb. |
| Wheat straw | 50c per acre |
| Oat and barley straw | 75c per acre |
| Corn stover | $1.50 per acre |

The following figures have been assumed to be approximately the cost of various tillage and harvesting operations:

| | |
|---|---|
| Double disking | $0.75 per acre |
| Plowing | 2.00 per acre |
| Harrowing | 0.20 per acre |
| Weeding | 0.75 per acre |
| Seeding grain and peas | 0.50 per acre |
| Cost of seed, treated | 1.00 per bushel |
| Harvesting grain | 3.50 per acre |
| Cost of marketing, including bags | 0.15 per cwt. |
| Cutting and treating seed potatoes | 3.00 per acre |
| Planting potatoes | 2.50 per acre |
| Planting corn | 0.50 per acre |
| Cultivation of corn and potatoes | 0.50 per acre |
| Harvesting corn | 2.50 per acre |
| Harvesting peas | 4.50 per acre |

In addition to the actual operation costs, it has been assumed that the land is valued at $50.00 an acre, on which an annual interest charge of 6 percent or $3.00 is allowed. Fifty cents an acre has also been allowed for taxes.

Based on these figures, the actual cost of raising wheat, barley, oats, corn, peas, and potatoes, exclusive of marketing costs, would be as follows:

ACRE COST OF RAISING WHEAT

| | Winter wheat after fallow | Spring wheat after fallow | After cultivated crop | After grain |
|---|---|---|---|---|
| 1. Double disking | $0.75 | $0.75 | $0.75 | -------- |
| 2. Plowing | 2.00 | 2.00 | -------- | $2.00 |
| 3. Harrowing | 0.80 | 1.00 | 0.40 | 0.40 |
| 4. Weeding | 1.50 | 1.50 | -------- | -------- |
| 5. Packing | -------- | -------- | -------- | 0.20 |
| 6. Seeding | 0.50 | 0.50 | 0.50 | 0.50 |
| 7. Cost of seed | 1.00 | 1.00 | 1.00 | 1.00 |
| 8. Harvesting | 3.50 | 3.50 | 3.50 | 3.50 |
| 9. Interest on land (6% of $50) | 6.00 | 6.00 | 3.00 | 3.00 |
| 10. Taxes | 1.00 | 1.00 | 0.50 | 0.50 |
| | $17.05 | $17.25 | $9.65 | $11.10 |

## ACRE COST OF RAISING SPRING BARLEY AND OATS

| | After fallow | After grain | After cultivated crop | After peas turned under |
|---|---|---|---|---|
| 1. Double disking | $0.75 | ------- | $0.75 | $1.50 |
| 2. Plowing | 2.00 | $2.00 | ------- | 2.00 |
| 3. Harrowing | 0.80 | 0.40 | 0.40 | 0.40 |
| 4. Packing | ------- | 0.20 | ------- | ------- |
| 5. Seeding | 0.50 | 0.50 | 0.50 | 0.50 |
| 6. Weeding | 1.50 | ------- | ------- | ------- |
| 7. Cost of seed | 0.85 | 0.85 | 0.85 | 3.10 |
| 8. Harvesting | 3.50 | 3.50 | 3.50 | 3.50 |
| 9. Interest on land | 6.00 | 3.00 | 3.00 | 6.00 |
| 10. Taxes | 1.00 | 0.50 | 0.50 | 1.00 |
| | $16.90 | $10.95 | $9.50 | $18.00 |

## ACRE COST OF RAISING CORN

| | After grain | After fallow | After rye turned under | After peas turned under |
|---|---|---|---|---|
| 1. Plowing | $2.00 | $2.00 | $2.00 | $2.00 |
| 2. Harrowing | 0.60 | 0.80 | 0.40 | 0.40 |
| 3. Planting | 0.50 | 0.50 | 0.50 | 0.50 |
| 4. Cost of seed | 0.40 | 0.40 | 0.40 | 0.40 |
| 5. Cultivating twice | 1.00 | 1.00 | 1.00 | 1.00 |
| 6. Harvesting | 2.50 | 2.50 | 2.50 | 2.50 |
| 7. Interest | 3.00 | 6.00 | 6.00 | 6.00 |
| 8. Taxes | .50 | 1.00 | 1.00 | 1.00 |
| 9. Disking | ------- | 1.50 | 0.75 | 0.75 |
| 10. Seed for green manure crop | ------- | ------- | 1.00 | 2.25 |
| 11. Seeding | ------- | ------- | 0.50 | 0.50 |
| 12. Harrowing | ------- | ------- | 0.20 | 0.20 |
| 13. Weeding | ------- | 1.50 | ------- | ------- |
| | $10.50 | $17.20 | $16.25 | $17.50 |

## ACRE COST OF RAISING PEAS

| | After grain | After peas |
|---|---|---|
| 1. Plowing | $2.00 | ------- |
| 2. Disking | ------- | $0.75 |
| 3. Harrowing | 0.60 | 0.60 |
| 4. Seeding | 0.50 | 0.50 |
| 5. Cost of seed | 2.25 | 2.25 |
| 6. Cultivating twice | 1.00 | 1.00 |
| 7. Harvesting | 4.50 | 4.50 |
| 8. Interest | 3.00 | 3.00 |
| 9. Taxes | 0.50 | 0.50 |
| | $14.35 | $13.10 |

## ACRE COST OF RAISING POTATOES AFTER GRAIN

| | |
|---|---|
| 1. Plowing | $2.00 |
| 2. Harrowing | 0.80 |
| 3. Planting | 2.50 |
| 4. Cost of seed (15 bu. at $1.20) | 18.00 |
| 5. Cutting and treating seed | 3.50 |
| 6. Cultivating three times | 1.50 |
| 7. Digging, picking and sorting | 7.50 |
| 8. Interest and taxes | 3.50 |
| | $39.30 |

In Table IX are listed the various rotations, grouped as previously, with the acre yield in pounds, the value of each crop, cost of producing it and the profit or loss per acre on each crop and on each rotation. Different conclusions might be drawn from the results of these rotations if different figures were used for crop values and production costs. It is believed, however, that the figures are relatively fair and will serve as an equitable basis for comparing the value of the different rotations.

According to the figures used, all rotations show a profit, though seven of them netted a profit of less than $1.00 an acre. There were more profitable rotations in Group 4, where fallowing was not practiced, than in any other group. The following rotations were the most profitable in the order named:

| | | Annual profit per acre on rotation |
|---|---|---|
| 1E. | Potatoes—fallow | $7.34 |
| 19. | Peas continuously | 5.65 |
| 21. | Spring wheat—peas | 5.59 |
| 9. | Spring wheat—corn—barley | 3.75 |
| 1A. | Winter wheat—fallow | 3.47 |
| 22. | Winter wheat—peas—winter wheat—fallow | 3.25 |
| 27. | Winter wheat—peas—peas | 3.02 |
| 1C. | Spring barley—fallow | 2.80 |

Of these eight rotations, three were in Group 1, where the land was alternately cropped and fallowed; four were in Group 4, where no fallow occurred; and one was in Group 3, with the fallow occurring once in four years. Of the eight rotations listed above, only four are in the list given on page 24 which showed a higher average seed yield per acre than the rotation, winter wheat—fallow. Two of these, Rotation 21, spring wheat—peas, and Rotation 9, spring wheat—corn—barley, returned a net average profit per acre more than that obtained from the rotation, winter wheat—fallow. No. 22, winter wheat—peas—winter wheat—fallow, showed a slightly less profit per acre than growing winter wheat after fallow, and No. 1C, spring barley—fallow, though producing more pounds per acre than winter wheat—fallow, did not return as great a profit because of the barley being valued at ¼c per pound less than the winter wheat.

With the assumed crop values and production costs, rotation 1E, potatoes—fallow, ranked highest. As pointed out previously, however, this rotation would be an impractical one for general practice on the dry lands of Eastern Oregon. The second rotation in point of profit was peas continuously, with peas valued at 2½c a pound. If the value of the peas were based on about their worth for feed, or the same as the values placed on corn, oats, and barley, 1¼c a pound, this rotation instead of showing a profit would have shown a slight loss.

Rotation 21, spring wheat—peas, which has been in progress eight years, showed a profit of $2.32 an acre more than the rotation, winter wheat—fallow. With the peas valued at 1¼c in this rotation, they would have been grown at a loss and the annual profit per acre on the rotation would have been reduced to a little less than $3.00 per acre.

Rotation 9, spring wheat—corn—barley, returned a profit of $3.75 an acre, a little more than the returns obtained from the standard rotation, winter wheat—fallow. A similar rotation, No. 8, with the same crops used in a different sequence, returned a profit of $2.36 per acre.

TABLE IX. AVERAGE YIELDS FOR THE YEARS 1912 TO 1923, INCLUSIVE, FOR EACH CROP GROWN IN THE ROTATION EXPERIMENTS, WITH VALUE OF THE CROP, COST OF PRODUCING IT, AND ANNUAL PROFIT PER ACRE FOR EACH CROP AND FOR EACH ROTATION

| Rotation No. | Rotation | Average acre yield | Value | Cost | Annual profit or loss per acre<br>On crop | Annual profit or loss per acre<br>On rotation |
|---|---|---|---|---|---|---|
| | | *lbs.* | | | | |
| | **Group 1. Fallow and cropped alternately** | | | | | |
| 1A. | Winter wheat—fallow | 1740 | $26.60 | $19.66 | $3.47 | $3.47 |
| 1B. | Spring wheat—fallow | 1428 | 21.92 | 19.39 | 1.27 | 1.27 |
| 1C. | Spring barley—fallow | 1978 | 25.47 | 19.87 | 2.80 | 2.80 |
| 1D. | Spring oats—fallow | 1603 | 20.79 | 19.30 | 0.75 | 0.75 |
| 1E. | Potatoes—fallow | 8172* | 73.55 | 58.88 | 7.34 | 7.34 |
| | **Group 2. Fallow once in three years** | | | | | |
| 2. | Spring wheat—spring wheat—fallow | | | | | |
| | Wheat after fallow | 1368 | 21.02 | 19.30 | 0.86 | ........ |
| | Wheat after wheat | 774 | 12.11 | 12.26 | —0.15 | 0.52 |
| 3. | Spring barley—spring barley—fallow | | | | | |
| | Barley after fallow | 1690 | 21.87 | 19.44 | 1.21 | ........ |
| | Barley after barley | 941 | 12.51 | 12.36 | 0.15 | 0.86 |
| 4. | Spring wheat—spring barley—fallow | | | | | |
| | Wheat after fallow | 1314 | 20.21 | 19.22 | 0.50 | ........ |
| | Barley after wheat | 1003 | 13.28 | 12.45 | 0.83 | 0.61 |
| 20. | Spring wheat—peas—fallow (8 yrs.) | | | | | |
| | Wheat after fallow | 1542 | 23.63 | 19.56 | 2.03 | ........ |
| | Peas after wheat | 624 | 15.60 | 15.29 | 0.31 | 1.46 |
| 25. | Winter wheat—spring rye—fallow (6 yrs.) | | | | | |
| | Winter wheat after fallow | 1572 | 24.08 | 19.41 | 2.34 | ........ |
| | Rye after wheat | 778 | 11.67 | 10.82 | 0.85 | 1.84 |
| | **Group 3. Fallow once in four years** | | | | | |
| 5. | Spring wheat—corn—spring wheat—fallow | | | | | |
| | Wheat after fallow | 1272 | 19.58 | 19.16 | 0.21 | ........ |
| | Wheat after corn | 1068 | 16.52 | 11.25 | 5.27 | ........ |
| | Corn after wheat | 706 | 10.32 | 11.56 | —1.24 | 1.11 |
| 6. | Spring wheat—peas—spring wheat—fallow | | | | | |
| | Wheat after fallow | 1356 | 20.84 | 19.28 | 0.78 | ........ |
| | Wheat after peas | 1188 | 18.32 | 11.43 | 6.89 | ........ |
| | Peas after wheat | 648 | 16.20 | 15.32 | 0.88 | 2.33 |
| 15. | Spring wheat—corn—oats—fallow (10 yrs.) | | | | | |
| | Wheat after fallow | 1350 | 20.75 | 19.28 | 0.74 | ........ |
| | Oats after corn | 1098 | 14.47 | 11.15 | 3.32 | ........ |
| | Corn after wheat | 801 | 11.51 | 11.70 | —0.19 | 1.15 |
| 17. | Spring wheat—barley—fallow—corn (10 yrs.) | | | | | |
| | Wheat after corn | 1404 | 21.56 | 11.76 | 9.80 | ........ |
| | Barley after wheat | 1219 | 15.99 | 12.78 | 3.21 | ........ |
| | Corn after fallow | 1008 | 14.10 | 18.71 | —2.30 | 2.10 |
| 18. | Spring wheat—barley—manured fallow—corn (10 yrs.) | | | | | |
| | Wheat after corn | 1428 | 21.92 | 11.79 | 10.13 | ........ |
| | Barley after wheat | 1402 | 18.27 | 13.05 | 5.22 | ........ |
| | Corn after manured fallow | 1126 | 15.57 | 22.89 | —3.66 | 2.01 |
| 22. | Winter wheat—peas—winter wheat—fallow (6 yrs.) | | | | | |
| | Wheat after fallow | 1572 | 24.08 | 19.41 | 2.34 | ........ |
| | Peas after wheat | 534 | 13.35 | 15.15 | —1.80 | ........ |
| | Wheat after peas | 1428 | 21.92 | 11.79 | 10.13 | 3.25 |
| 23. | Winter wheat—potatoes—winter wheat—fallow (6 yrs.) | | | | | |
| | Wheat after fallow | 1428 | 21.92 | 19.19 | 1.37 | ........ |
| | Wheat after potatoes | 1314 | 20.21 | 11.62 | 8.59 | ........ |
| | Potatoes after wheat | 5214† | 44.32 | 45.95 | —1.63 | 2.43 |

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*10% deducted for unmarketable tubers.

†15% deducted for unmarketable tubers.

TABLE IX (CONTINUED). AVERAGE YIELDS IN ROTATION EXPERIMENTS

| Rotation No. | Rotation | Average acre yield | Value | Cost | Annual profit or loss per acre | |
|---|---|---|---|---|---|---|
| | | | | | On crop | On rotation |
| | | *lbs.* | | | | |
| | **Group 3. Fallow once in four years (continued)** | | | | | |
| 28. | Winter wheat—peas—peas—fallow (6 yrs.) | | | | | |
| | Wheat after fallow | 1692 | 25.88 | 19.59 | 3.14 | ....... |
| | Peas after wheat | 630 | 15.75 | 15.30 | 0.45 | ....... |
| | Peas after peas | 684 | 17.10 | 14.13 | 2.97 | 2.42 |
| | **Group 4. No fallow** | | | | | |
| 8. | Spring wheat—barley—corn | | | | | |
| | Wheat after corn | 1026 | 15.89 | 11.19 | 4.70 | ....... |
| | Barley after wheat | 1046 | 13.82 | 12.52 | 1.30 | ....... |
| | Corn after barley | 918 | 12.97 | 11.88 | 1.09 | 2.36 |
| 9. | Spring wheat—corn—barley | | | | | |
| | Wheat after barley | 1062 | 16.43 | 12.69 | 3.74 | ....... |
| | Corn after wheat | 963 | 13.53 | 11.94 | 1.59 | ....... |
| | Barley after corn | 1334 | 17.42 | 11.50 | 5.92 | 3.75 |
| 10. | Spring wheat—spring barley—potatoes | | | | | |
| | Wheat after potatoes | 1296 | 19.94 | 11.59 | 8.35 | ....... |
| | Barley after wheat | 1042 | 13.77 | 12.51 | 1.26 | ....... |
| | Potatoes after barley | 5094* | 43.30 | 45.80 | —2.50 | 2.37 |
| 19. | Peas continuously | | | | | |
| | Peas after peas | 798 | 19.95 | 14.30 | 5.65 | 5.65 |
| 21. | Spring wheat—peas (8 yrs.) | | | | | |
| | Wheat after peas | 1482 | 22.73 | 11.87 | 10.86 | ....... |
| | Peas after wheat | 624 | 15.60 | 15.29 | 0.31 | 5.59 |
| 24. | Winter wheat—spring rye—peas (6 yrs) | | | | | |
| | Wheat after peas | 1194 | 18.41 | 11.44 | 6.97 | ....... |
| | Rye after wheat | 678 | 10.17 | 10.67 | —0.50 | .. |
| | Peas after rye | 528 | 13.20 | 15.14 | —1.94 | 1.51 |
| 26. | Winter wheat—corn (7 yrs.) | | | | | |
| | Wheat after corn | 1104 | 17.06 | 11.31 | 5.75 | ....... |
| | Corn after wheat | 566 | 8.57 | 11.35 | —2.78 | 1.48 |
| 27. | Winter wheat—peas—peas (6 yrs.) | | | | | |
| | Wheat after peas | 1158 | 17.87 | 11.39 | 6.48 | ....... |
| | Peas after wheat | 612 | 15.30 | 15.27 | 0.03 | . |
| | Peas after peas | 666 | 16.65 | 14.10 | 2.55 | 3.02 |
| 29. | Corn continuously (6 yrs.) | | | | | |
| | Corn after corn | 963 | 13.53 | 11.94 | 1.59 | 1.59 |
| | **Group 5. The use of green manure crops** | | | | | |
| 7. | Spring wheat—spring barley—peas turned under—fallow | | | | | |
| | Wheat after fallow and peas turned under | 1542 | 23.63 | 26.76 | —1.04 | ....... |
| | Barley after wheat | 1286 | 16.82 | 12.88 | 3.94 | 0.20 |
| 11. | Spring wheat—spring barley—rye turned under—corn | | | | | |
| | Wheat after corn | 1134 | 17.51 | 11.35 | 6.16 | ....... |
| | Barley after wheat | 1157 | 15.21 | 12.69 | 2.52 | ....... |
| | Corn after rye turned under | 1036 | 14.45 | 17.80 | —1.68 | 1.33 |
| 12. | Spring wheat—spring barley—peas turned under—corn | | | | | |
| | Wheat after corn | 1158 | 17.87 | 11.39 | 6.48 | . . |
| | Barley after wheat | 1109 | 14.61 | 12.61 | 2.00 | ....... |
| | Corn after peas turned under | 1193 | 16.41 | 19.29 | —1.44 | 1.40 |
| 13. | Spring wheat—spring wheat—peas turned under—spring barley | | | | | |
| | Wheat after barley | 846 | 13.19 | 12.37 | 0.82 | ....... |
| | Wheat after wheat | 828 | 12.92 | 12.34 | 0.58 | . . |
| | Barley after peas turned under | 1450 | 18.87 | 20.18 | —0.66 | 0.02 |
| 14. | Winter wheat—corn—winter wheat—peas turned under—winter wheat—potatoes | | | | | |
| | Wheat after peas turned under | 1296 | 1994 | 20.04 | —0.05 | ....... |
| | Corn after wheat | 554 | 8.42 | 11.33 | —2.91 | ....... |
| | Wheat after corn | 1050 | 16.25 | 11.23 | 5.02 | ... |
| | Potatoes after wheat | 4254* | 36.16 | 44.72 | —8.56 | . |
| | Wheat after potatoes | 1170 | 18.05 | 11.41 | 6.64 | 0.01 |

*15% deducted for unmarketable tubers.

TABLE IX (CONCLUDED). AVERAGE YIELDS IN ROTATION EXPERIMENTS

| Rotation No. | Rotation | Average acre yield | Value | Cost | Annual profit or loss per acre | |
|---|---|---|---|---|---|---|
| | | | | | On crop | On rotation |
| | | *lbs.* | | | | |
| | Group 5. The use of green manure crops (continued) | | | | | |
| 16. | Spring oats—spring barley—peas turned under—corn (10 yrs.) | | | | | |
| | Oats after corn | 1424 | 18.55 | 11.64 | 6.91 | ....... |
| | Barley after oats | 1406 | 18.32 | 13.06 | 5.26 | ....... |
| | Corn after peas turned under | 1148 | 15.85 | 19.22 | —1.68 | 2.20 |

## SUMMARY BY CROPS OF YIELDS IN ROTATION EXPERIMENTS

In Table X is a summary by crops of the yields obtained in the rotation experiments at Moro, with the yield of each crop expressed in bushels per acre, and the profit or loss shown for each crop. This table shows that in the twelve rotations in which corn was grown it was produced at a loss in nine. In four of these rotations, however, the corn followed a green manure crop, and the total cost of growing the green manure crop was charged to the corn. Corn showed a slight profit in Rotation 8, spring wheat—barley—corn, and in Rotation 9, spring wheat—corn—barley. In only one other instance did corn prove profitable—when grown continuously in Rotation 29, which has been in progress only six years.

Peas showed a net loss in two rotations, after wheat in No. 22, and after rye in No. 24, and showed only a small profit when grown after small grains in five other rotations. Peas following peas returned a profit of more than $2.50 an acre in three rotations, Nos. 19, 27, and 28.

Potatoes showed a loss in three rotations in which the crop followed grain, and showed a profit only when grown after fallow in Rotation 1E.

Spring wheat, which occurred in twenty-one rotations, was grown at a loss in only two, after wheat in Rotation 2, and after peas turned under in Rotation 7. When grown after fallow, spring wheat returned a profit of less than $2.00 an acre in five rotations out of seven. When grown after corn, spring wheat returned a profit of from $4.70 to $10.13 an acre, averaging higher than winter wheat after corn in two rotations, Nos. 14 and 26. In the two rotations in which spring wheat occurred after peas, a net profit of $6.89 was returned in one and $10.86 per acre in the other.

Winter wheat after fallow occurred in five rotations and returned a profit of $1.37 to $3.47 per acre, or considerably higher than the profit returned from spring wheat after fallow. In the three rotations where winter wheat was grown after peas, the profit ranged from $6.48 to $10.13 per acre, averaging about the same as spring wheat after peas.

Barley was grown in fourteen rotations and, like the other small grains, returned the highest net profit when grown after a cultivated crop. Barley was produced at a loss in only one rotation, No. 13, when grown after peas turned under. Barley was grown after other small grains in ten rotations, returning a profit as high as $5.26 an acre after oats in Rotation 16, and as low as 15 cents an acre when grown after barley in Rotation 3.

TABLE X. A SUMMARY BY CROPS OF YIELDS OBTAINED IN ROTATION EXPERIMENTS AND PROFIT OR LOSS FOR EACH CROP

| Crop, rotation number, and period grown | Average acre yield | Profit or loss |
|---|---|---|
| | *bu.* | |
| Winter wheat | | |
| After fallow | | |
| Rotation 1A | 29.0 | $3.47 |
| Rotation 22 (6 yrs.) | 26.2 | 2.34 |
| Rotation 23 (6 yrs.) | 23.8 | 1.37 |
| Rotation 25 (6 yrs.) | 26.2 | 2.34 |
| Rotation 28 (6 yrs.) | 28.2 | 3.14 |
| Average | 27.1 | $2.69 |
| After corn | | |
| Rotation 14 | 17.5 | $5.02 |
| Rotation 26 (7 yrs.) | 18.4 | 5.75 |
| Average | 17.8 | $5.29 |
| After potatoes | | |
| Rotation 14 | 19.5 | $6.64 |
| Rotation 23 (6 yrs.) | 21.9 | 8.59 |
| Average | 20.3 | $7.29 |
| After peas turned under | | |
| Rotation 14 | 21.6 | —$0.05 |
| After peas | | |
| Rotation 22 (6 yrs.) | 23.8 | $10.13 |
| Rotation 24 (6 yrs.) | 19.9 | 6.97 |
| Rotation 27 (6 yrs.) | 19.3 | 6.48 |
| Average | 21.0 | $7.86 |
| Spring wheat | | |
| After fallow | | |
| Rotation 1B | 23.8 | $1.27 |
| Rotation 2 | 22.8 | 0.86 |
| Rotation 4 | 21.9 | 0.50 |
| Rotation 5 | 21.2 | 0.21 |
| Rotation 6 | 22.6 | 0.78 |
| Rotation 15 (10 yrs.) | 22.5 | 0.74 |
| Rotation 20 (8 yrs.) | 25.7 | 2.03 |
| Average | 22.8 | $0.86 |
| After barley | | |
| Rotation 9 | 17.7 | $3.74 |
| Rotation 13 | 14.1 | 0.82 |
| Average | 15.9 | $2.28 |
| After wheat | | |
| Rotation 2 | 12.9 | —$0.15 |
| Rotation 13 | 13.8 | 0.58 |
| Average | 13.4 | $0.22 |
| After corn | | |
| Rotation 5 | 17.8 | $5.27 |
| Rotation 8 | 17.1 | 4.70 |
| Rotation 11 | 18.9 | 6.16 |
| Rotation 12 | 19.3 | 6.48 |
| Rotation 17 (10 yrs.) | 23.4 | 9.80 |
| Rotation 18 (10 yrs.) | 23.8 | 10.13 |
| Average | 19.8 | $6.92 |
| After potatoes | | |
| Rotation 10 | 21.6 | $8.35 |
| After peas | | |
| Rotation 6 | 19.8 | $ 6.89 |
| Rotation 21 (8 yrs.) | 24.7 | 10.86 |
| Average | 21.8 | $ 8.48 |
| After peas turned under and fallow | | |
| Rotation 7 | 25.7 | —1.04 |

TABLE X (CONTINUED). SUMMARY OF YIELDS IN ROTATION EXPERIMENTS

| Crop, rotation number, and period grown | Average acre yield | Profit or loss |
|---|---|---|
| | *bu.* | |
| **Barley** | | |
| After fallow | | |
| Rotation 3 | 35.2 | $1.21 |
| Rotation 1C | 41.2 | 2.80 |
| Average | 38.2 | $2.00 |
| After wheat | | |
| Rotation 4 | 20.9 | $0.83 |
| Rotation 7 | 26.8 | 3.94 |
| Rotation 8 | 21.8 | 1.30 |
| Rotation 10 | 21.7 | 1.26 |
| Rotation 11 | 24.1 | 2.52 |
| Rotation 12 | 23.1 | 2.00 |
| Rotation 17 (10 yrs.) | 25.4 | 3.21 |
| Rotation 18 (10 yrs.) | 29.2 | 5.22 |
| Average | 23.9 | $2.46 |
| After barley | | |
| Rotation 3 | 19.6 | $0.15 |
| After oats | | |
| Rotation 16 (10 yrs.) | 29.3 | $5.26 |
| After corn | | |
| Rotation 9 | 27.8 | $5.92 |
| After peas turned under | | |
| Rotation 13 | 30.2 | —$0.66 |
| **Spring rye** | | |
| After winter wheat | | |
| Rotation 24 (6 yrs.) | 11.8 | —$0.50 |
| Rotation 25 (6 yrs.) | 13.5 | 0.85 |
| Average | 12.7 | $0.18 |
| **Corn** | | |
| After wheat | | |
| Rotation 5 | 12.6 | —$1.24 |
| Rotation 9 | 17.2 | 1.59 |
| Rotation 14 | 9.9 | —2.91 |
| Rotation 15 (10 yrs.) | 14.3 | —0.19 |
| Rotation 26 (7 yrs.) | 10.1 | —2.78 |
| Average | 13.0 | —$0.98 |
| After barley | | |
| Rotation 8 | 16.4 | $1.09 |
| After fallow | | |
| Rotation 17 (10 yrs.) | 18.0 | —$2.30 |
| After peas turned under | | |
| Rotation 12 | 21.3 | —$1.44 |
| Rotation 16 (10 yrs.) | 20.5 | —1.68 |
| Average | 20.9 | —$1.59 |
| After rye turned under | | |
| Rotation 11 | 18.5 | —$1.68 |
| After manured fallow | | |
| Rotation 18 (10 yrs.) | 20.1 | —$3.66 |
| After corn | | |
| Rotation 29 (6 yrs.) | 17.2 | 1.59 |
| **Oats** | | |
| After fallow | | |
| Rotation 1D | 50.1 | $0.75 |
| After corn | | |
| Rotation 15 (10 yrs.) | 34.3 | $3.32 |
| Rotation 16 (10 yrs.) | 44.5 | 6.91 |
| Average | 39.4 | $5.11 |

TABLE X (CONCLUDED). SUMMARY OF YIELDS IN ROTATION EXPERIMENTS

| Crop, rotation number, and period grown | Average acre yield | Profit or loss |
|---|---|---|
| | *bu.* | |
| **Potatoes** | | |
| After fallow | | |
| Rotation 1E | 136.2 | $7.34 |
| After winter wheat | | |
| Rotation 14 | 70.9 | —$8.56 |
| Rotation 23 (6 yrs.) | 86.9 | —1.63 |
| Average | 76.2 | —$6.25 |
| After barley | | |
| Rotation 10 | 84.9 | —$2.50 |
| **Peas** | | |
| After spring wheat | | |
| Rotation 6 | 10.8 | $0.88 |
| Rotation 20 (8 yrs.) | 10.4 | 0.31 |
| Rotation 21 (8 yrs.) | 10.4 | 0.31 |
| Average | 10.6 | $0.55 |
| After winter wheat | | |
| Rotation 22 (6 yrs.) | 8.9 | —$1.80 |
| Rotation 27 (6 yrs.) | 10.2 | 0.03 |
| Rotation 28 (6 yrs.) | 10.5 | 0.45 |
| Average | 9.9 | —$0.44 |
| After rye | | |
| Rotation 24 (6 yrs.) | 8.8 | —$1.94 |
| After peas | | |
| Rotation 19 | 13.3 | $5.65 |
| Rotation 27 (6 yrs.) | 11.1 | 2.55 |
| Rotation 28 (6 yrs.) | 11.4 | 2.97 |
| Average | 12.3 | $4.20 |

**Winter wheat.** In agricultural importance winter wheat takes first rank among the crops grown in Eastern Oregon. In the counties of Wasco, Sherman, Morrow, Gilliam, and Umatilla, the acreage sown to this crop annually far exceeds that sown to all other crops combined. It is one of the important farm crops in all other counties east of the Cascades, though in the mountain valleys and higher plateau regions hav and spring-sown crops considerably exceed winter wheat in total acreage. When grown after fallow, no crop except perhaps winter rye will equal winter wheat in total yield. A good variety of spring barley sown early may exceed winter wheat in grain yield, but in total crop weight winter wheat will generally yield about one-third more than any spring-sown grain. In the vicinity of Moro winter wheat after fallow usually produces from two to four tons of hay per acre. The small grains, mostly winter wheat, are extensively used for hay in Eastern Oregon, comprising in many counties from 50 to 85 percent of the total acreage devoted to hay and forage.

Wherever it can be grown, winter wheat is one of the most valuable dry-land crops. Because it makes a large part of its growth in cool weather, the water requirement of winter wheat is lower than that of spring wheat, barley, or oats. The earlier maturity also frequently enables winter wheat to escape drought that might seriously injure spring-sown grain. In addition to its superior yield as a dry-land crop, another item of much importance to the farmer is the fact that winter wheat is sown in the fall when farm work generally is slack. The spring sowing of grain comes at one of the busiest times of the year for the dry farmer, who must have his land spring-disked or plowed early if he gets maximum returns.

When the rotation experiments for the Moro Branch Station were planned in 1910, spring wheat was chosen as the principal grain crop to be used although at that time winter wheat was the most extensively grown crop in Eastern Oregon. The reason for including spring wheat as a major crop in the rotation experiments, as stated by Superintendent Umberger at that time, was "not because spring wheat is the most successful grain crop but because there is more generally a certainty of securing a stand of spring wheat every year than of winter grain and for comparative purposes spring wheat is as indicative of different soil influences as the winter varieties.". Because it has been found that winter wheat shows a comparatively greater benefit from fallow than spring wheat, and because of the higher yields obtained from winter wheat, in 1916 several rotations with winter wheat were added. Since 1920 all the check plots have been sown to winter wheat instead of spring wheat.

The average winter wheat yields obtained in the rotation experiments are shown in Table X. The average yield for winter wheat after fallow in Rotation 1A is that obtained each year from eight one-tenth-acre plots in the tillage experiments for each of the years 1913 to 1923, inclusive. The yield for 1912 was that obtained in the varietal trial for the same variety used in the tillage experiments (Alberta Red, C. I. No. 2979). The yields of winter wheat after fallow in the other rotations are averages for single one-tenth-acre plots for six years, as indicated in Table X. A period of fallow also occurred only once in every three or four years in Rotations 22, 23, 25, and 28, and other crops than winter wheat were grown in these rotations.

The averages included in Table X are weighted and are not strictly comparable, but it is thought that they can safely be used as a basis for comparing differences in yields and profits in growing winter wheat after fallow and after different crops.

The average yield for winter wheat after fallow for all rotations, as shown in Table X, was 27.1 bushels per acre and the average annual profit $2.69 per acre. The next highest average yield for this crop was obtained after peas turned under, the wheat in this rotation being grown at a loss if the cost of the green manure crop is charged against it. Winter wheat after potatoes returned fair yields and a high average profit per acre, but the potatoes in both rotations were grown at a loss.

Winter wheat after peas returned an average yield of 6.1 bushels per acre less than winter wheat after fallow. Partly to compensate for this reduced yield is the lower expense of seed-bed preparation for winter wheat after peas. The winter wheat is sown on disked pea land without plowing. In annual profit per acre, growing winter wheat after peas averaged $7.86 per acre, or higher than when grown after corn, potatoes, or fallow. Whether winter wheat can be profitably grown in rotation with field peas will depend upon whether the peas can be grown without too great a loss. They did not quite pay production costs in the three rotations in which they were grown after wheat for a six-year period, as shown in Table X. When grown for pasture, with harvest cost eliminated, peas grown in a rotation with wheat might be profitable for farmers who can handle hogs or sheep.

Winter wheat after corn has averaged 9.3 bushels per acre less than winter wheat after fallow. This decrease in yield, as in the case of field peas, is partly compensated by the reduced cost of seed-bed preparation for winter wheat after corn. The winter wheat is also sown on disked corn ground without plowing.

Whether corn can profitably be used in a rotation with winter wheat will depend, as in the case of peas, upon the profit made from the corn. If these crops can be grown without a loss, the growing of winter wheat after them might prove more profitable than growing winter wheat after fallow because of the lower expense involved in seed-bed preparation.

In farm practice the principal difficulty in growing winter wheat in any crop rotation without fallow is that of getting a stand of winter wheat because of the normal dry autumn weather which prevails in most sections of Eastern Oregon. A comparatively light rainfall may put the fallow soil in condition to germinate and keep winter wheat growing. When sown on corn or pea ground, failure to get a stand of winter wheat may result either because of insufficient moisture to germinate the wheat or insufficient moisture to keep the wheat growing after germination. Because winter wheat as a rule considerably outyields spring wheat and because of the extra expense of reseeding if a failure or thin stand results from sowing winter wheat on corn or pea land, the growing of winter wheat after fallow will probably remain for a long time the most popular method of growing this crop on the drier lands of Eastern Oregon.

The results obtained on the typical Columbia Basin silt loam soil of the Moro Station, where the average annual precipitation during the period of the experiments was a little more than twelve inches, amply justify the statement that in the more favored sections of Eastern Oregon, where the average annual precipitation is fourteen inches or more, corn or peas grown in a rotation with winter wheat would prove more profitable in the long run than the present winter wheat-fallow system of farming, especially in locations favorably situated for livestock raising. This statement is based on the assumption that the yields of winter wheat, corn, and peas would be higher than at Moro and that the reduction in yields of winter wheat after peas and after corn as compared with growing winter wheat after fallow would be proportionately the same as at Moro. The soil fertility problem incident to any one-crop system of farming may sometime compel a change in the present wheat-fallow system now so universally practiced in Eastern Oregon. Or such a change may be brought about by difficulty in controlling noxious weeds, insect pests, or wheat diseases.

**Spring wheat.** In total acreage and production, spring wheat is the cereal second in importance in Eastern Oregon. In a few counties, the total acreage exceeds that of winter wheat. Even in counties devoted primarily to winter wheat production, the raising of spring wheat always will be important because of the necessity of sometimes reseeding to spring wheat land sown to winter wheat.

A direct comparison of the difference in average yields of spring and winter wheat after fallow for the twelve-year period is best obtained from the yields of Rotations 1A and 1B, as shown in Table X. During this period the average yield of winter wheat after fallow has been 5.2 bushels per acre greater than that of spring wheat after fallow. The average yield of six varieties of Turkey winter wheat after fallow in the varietal experiments for the ten-year period, 1914 to 1923, inclusive, was 31.5 bushels per acre and the average yield of the two best spring wheat varieties after fallow for the same period was 26.3 bushels per acre, a difference also of 5.2 bushels per acre in favor of winter wheat.

The average yields of spring wheat after the cultivated crops corn, peas, and potatoes, as recorded in Table X, are a little higher than those of winter wheat grown after these crops. Winter wheat, however, has been grown after a cultivated crop in only one rotation, No. 14, for the whole period of twelve years. In this rotation winter wheat after corn has averaged slightly less in yield than spring wheat after corn in the rotations which have been in progress twelve years. The low winter wheat yield in Rotation 14 may be partly due to its unfavorable location for winter wheat. The difference in yield, however, in Eastern Oregon between winter wheat and spring wheat sown after cultivated crops is not so great as when sown after fallow, when the yield of winter wheat nearly always exceeds that of spring wheat. In seasons when the autumn rains come early enough, winter wheat on corn or pea land may considerably outyield spring wheat on similar land, but when a thin stand or late emergence of winter wheat occurs because of moisture deficiency the reverse may happen. At present the results of the rotation experiments show an advantage in yield of spring wheat over that of winter wheat when these crops are sown after corn, peas, or potatoes, but it is thought that after the rotations have been in progress a few more years, the advantage will be slightly in favor of winter wheat.

Of the seven methods of growing spring wheat shown in Table X, the highest yields were obtained after peas turned under for green manure and fallow. Because this method is equivalent to, but more expensive than, two years of fallow, the yields were not high enough to justify the extra expense. The next highest yields were obtained by growing this crop after fallow. Spring wheat after fallow occurred in seven rotations and the average yield obtained was 22.8 bushels per acre with an average annual profit of $0.86 per acre as against $2.69 per acre for growing winter wheat after fallow. In only one of these rotations, No. 1B, was the spring wheat regularly alternated with fallow. In the other rotations the fallow occurred once every two, three, or four years.

The average yield of spring wheat after peas was only one bushel per acre less than that obtained after fallow. If peas can be grown at not too great a loss, spring wheat grown after this crop would be considerably more profitable than when grown after fallow. The spring wheat after peas returned a net average profit per acre of $8.48 in two rotations. When valued at 2½c per pound, the peas also were grown at a slight profit after spring wheat in three rotations. The regular rotation, No. 21, of spring wheat—peas also produced an average net profit per acre of $5.59 per acre, or $2.12 per acre more than Rotation 1A, winter wheat—fallow. The yields of spring wheat after potatoes have also been nearly as high as after fallow. After corn, spring wheat yields have averaged three bushels per acre less than after fallow. The yields of spring wheat after barley and after wheat are significantly lower than after a cultivated crop or after fallow, though in only one rotation out of four was the wheat after a grain crop produced at a loss. Spring wheat after barley has averaged 2.5 bushels per acre more than spring wheat after wheat.

The data in Table X show quite conclusively that if Eastern Oregon farmers were limited to the growing of spring wheat, the summer-fallow might advantageously be entirely replaced by the introduction of corn or peas in the rotation. This has been found true in the extensive crop rotation experiments in the northern Great Plains by the Office of Dry Land Agriculture of the United States Department of Agriculture and by state experiment stations. The investigations conducted in that region generally show a reduction in yield of spring wheat after corn as compared with growing this crop after fallow, but on account of the added expense of the season of fallow and the cheapness of seed-bed preparation in growing spring wheat after corn, more profitable returns can generally be obtained by the substitution of corn for the fallow.

**Barley.** Barley is the standard feed crop of Eastern Oregon. It is fed to all classes of livestock, being nearly always first steamed and rolled or ground. In actual pounds of seed per acre the average yield of spring barley after fallow has been a little more at Moro than that of winter wheat for the twelve-year period 1912 to 1923, inclusive, and considerably more than that of any other spring-sown crop.

In Table X are given the average yields obtained from growing barley after fallow, after wheat, after barley, after oats, after corn, and after peas turned under for green manure with the average annual profit per acre for each method of growing the crop. Highest average yields were obtained by growing this crop after fallow in rotations 1C and 3, and the annual profit per acre was considerably higher than growing spring wheat after fallow with the value of the crop figured at ¼c per pound less. The next highest yields were obtained from growing barley after peas turned under, a considerably more expensive method of growing the crop than after bare fallow. Barley after oats in Rotation 16 for ten years gave an average yield of 8.9 bushels per acre less than growing the barley after fallow. A reduction in yield of 10.4 bushels per acre was obtained in Rotation 9 from growing this crop after corn as compared with the yields obtained after fallow. Barley is admirably adapted to most sections of Eastern Oregon and should have a prominent place in any rotation system which includes spring-sown crops. Barley is one of the best grain crops to grow after corn.

**Oats.** In Eastern Oregon the acreage sown to oats is less than that of any of the other small grains. As a feed crop, barley largely takes the place of oats in this region. The average yields in pounds per acre of oats and barley after fallow, as shown in Table III, are considerably in favor of barley, this crop averaging 375 pounds per acre more for the twelve-year period than oats. As is shown in Table X, the average yield of oats after corn was 39.4 bushels or 1260.8 lbs. per acre and the average yield of barley after corn 27.8 bushels or 1334.4 pounds per acre, indicating also that when grown after corn, barley is the more profitable crop in this region if the value per pound is assumed to be equal. One objection to oats is that the crop is not very well adapted to harvesting with the combined harvester. The loss from shattering when left standing in the field after ripening is considerably greater in oats than in most varieties of barley or wheat.

**Rye.** Spring rye is used in two rotations both of which have been in operation only six years. The yields of this crop after winter wheat in both rotations are so low as to indicate its unsuitability for use in any rotation system in Eastern Oregon. Winter rye would probably give higher yields than spring rye, but at Moro the seed yields of winter rye after fallow have nearly always been much less than those of winter wheat after fallow. Because of its hardiness and its ability to grow in colder weather than wheat, rye makes an excellent pasture crop, but its usefulness is apparently limited to the colder and drier sections of Central Oregon and to limited areas in the Columbia Basin with shallow, sandy soil. Rye is a poor crop to grow on a wheat farm because it volunteers and becomes an objectionable mixture in the wheat.

**Corn.** Corn is the principal cultivated crop grown in rotations with small grains in the northern half of the United States. It is well suited for that purpose because it requires late seeding and matures after the grain harvest is finished, thus more equally distributing farm labor. Seed-bed preparation for small grains after a cultivated crop like corn is inexpensive, a double disking and harrowing usually being the only operations necessary.

Aside from its general lack of adaptability to climatic conditions in many parts of Eastern Oregon, the growing of corn has several disadvantages for the dry farmer, whose major crop is wheat. The growing of corn requires extra machinery and equipment and considerable hand labor if harvested. The growing of corn also presupposes the handling of livestock, for which many of the dry farms are not well adapted. In locations favorable for the raising of stock, corn, where it can be grown, may be found profitable if the crop is largely utilized for pasture. The comparatively low seed yields obtained from corn on most of the dry lands of Eastern Oregon and its exclusion from other areas because of too low temperatures during the growing season, preclude the possibility of the crop ever being a very important one. Most of the flint and many of the earlier-maturing dent varieties like Northwestern Dent, Minnesota No. 13, and Minnesota No. 23, will generally mature seed in the Columbia Basin and Blue Mountain region where the altitude is less than three thousand feet. In the central plateau region and in the higher altitudes in other sections, corn cannot be successfully grown because of the low summer temperatures. In these areas sunflowers are being grown for silage to a limited extent, but mostly under irrigation. On the dry lands, sunflowers have not shown much promise.

In Table X are given the yields of corn for the rotation experiments at Moro after fallow and after various crops. The highest average yield of corn, 20.9 bushels per acre, was obtained by growing it after peas turned under for green manure. The yields of corn obtained after green manure crops, after fallow and after manured fallow, as shown in Table X, were not nearly high enough to pay for the cost of producing the crop by these methods. In pounds per acre, the average yield of corn after fallow was not nearly as high as the yields of winter wheat, spring wheat, or spring barley after fallow.

The average seed yields of corn obtained after wheat in all rotations were 13.0 bushels per acre, too low to be profitable unless used for pasture so as to avoid the expense of harvesting. The yields of stover averaged about 1.5 tons per acre for all rotations. Some of the rotations with corn and spring grains, especially rotations 8 and 9, which have been previously discussed, have returned higher average annual seed yields and higher net profits per acre than most of the other rotations tried. In fact, the growing of corn as a substitute for fallow could be amply justified from the results obtained at the Moro Branch Station if spring-sown crops only were considered. As a fallow substitute in a rotation with winter wheat the results are not so favorable, though indicative of profitable returns in sections of higher rainfall. At Moro the reduction of 9.3 bushels in the acre yield of winter wheat after corn as compared with winter wheat after fallow is too great a margin to be made up by any probable profits from growing the corn. Corn after winter wheat, too, in rotations 14 and 26 yielded less than corn after spring wheat. Most of the rotations with corn and spring grain, however, show a greater average annual profit per acre than growing spring wheat after fallow. Another important item to be considered is the possibility of increasing corn yields by the production of higher-yielding and better adapted dry-land corn varieties. Large annual imports of corn into the Northwest make corn culture desirable in sections of higher rainfall.

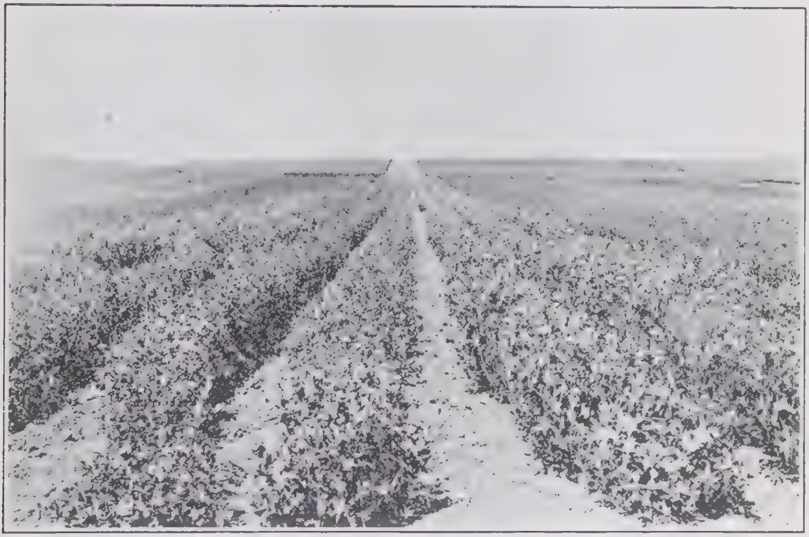

Fig. 2. Field peas grown on cultivated rows in a rotation with wheat.

**Field peas.** Field peas have been grown in the rotation experiments as a cultivated crop for the twelve-year period, 1912 to 1923, inclusive. Peas have some advantages over corn as a substitute for fallow for the dry lands of Eastern Oregon. Being a legume, they will aid in the solving of any soil fertility problems likely to arise from the continual growing of such crops as corn and wheat. As peas are comparatively a cool weather crop, the areas to which they are adapted in Eastern Oregon are not quite so restricted as those of corn, although in certain localities summer frosts may sometimes prevent the forming of a normal seed crop. If sown early in the spring, field peas make a fairly good growth and, as shown in Table X, will average from eight to twelve bushels per acre in seed yield when sown after grain crops. While this yield is lower than that obtained from corn, the market price for peas is generally considerably higher than that of corn or the small grains.

The yields of grain following peas have been higher than grain yields following corn. Winter wheat and spring wheat averaged about two bushels per acre more after peas than after corn, as is shown in Table X.

Aside from the low yields obtained, the principal objection to field peas is that they require early spring seeding at a time when the dry farmer is busy plowing and preparing his ground for fallow. The crop, too, usually ripens at about the same time as winter wheat, thus competing with that crop from the labor standpoint. The harvesting of peas for seed with a mower, hay-rake, and stationary thresher, also is more expensive than harvesting small grains by the methods generally employed on the dry lands of Eastern Oregon. Experiments have been conducted in Eastern Oregon on pasturing peas with hogs and sheep, and the results indicate that this crop can be successfully used for that purpose.

**Potatoes.** Potatoes have been grown in the rotation experiments after fallow, after winter wheat, and after barley. The average yield of potatoes after fallow for the twelve-year period, 1912 to 1923, inclusive, was 136.2 bushels per acre. The yields after winter wheat and after barley were 76.2 and 84.9 bushels per acre, respectively. The quality of the potatoes after fallow has generally been fair, and careful selection to eliminate disease or the securing of disease-free seed at frequent intervals would make it possible to grow at least enough potatoes on the dry lands of Eastern Oregon to supply local demands. To grow potatoes as a commercial crop on the dry lands in competition with irrigated or more humid sections would be impractical.

**Alfalfa.** Alfalfa has not been used in any of the regular rotation experiments, but the crop has been grown on the Station and considerable information obtained upon its effect on subsequent grain crops. In 1916, spring wheat, oats, barley, and corn were grown on land which had grown alfalfa in 1913 and 1914 and been left fallow in 1915. In every instance there was a reduction in yield of these crops as compared with the same crops grown on similar ground which had not grown alfalfa. In 1917, one acre of ground which had grown alfalfa in 1913, 1914, and 1915, and which was fallowed in 1916 was sown to spring wheat. It produced 15.9 bushels per acre, while an adjacent acre of ground, which had been alternately cropped and fallowed, produced 20.7 bushels per acre of the same variety of spring wheat.

In 1918 several rotation experiments were started on ground on which alfalfa had been grown in 1914 to 1917, inclusive, and which had been left fallow in 1918. The average yield of spring wheat in 1918 on the check plots of the rotation series which had never grown alfalfa was 17.5 bushels per acre. The average yield of spring wheat on three plots which had previously grown alfalfa was only 13.8 bushels per acre, a reduction of four bushels. The average yield of winter wheat in 1918 on old alfalfa ground which was fallowed in 1917 was 3.8 bushels per acre less than the average yield of adjacent plots on which alfalfa had never been grown. Grain yields following alfalfa are reduced for at least two crops even when the alfalfa is followed by a season of fallow and the second grain crop preceded by fallow.

Alfalfa, like other perennial crops which have been tried on the Station, requires considerable cultivation to keep it free from weeds. The low yield of hay per acre (from one to one and a half tons), together with the apparent reduction in yield of wheat following alfalfa, precludes the possibility of making this crop a profitable one for most of the dry lands of Eastern Oregon. In sections with higher precipitation than at Moro, it may prove to be a paying crop if, with higher yields of hay, it has the beneficial effect on soil fertility and increasing wheat yields which usually accompany the growing of alfalfa in humid, sub-humid, or irrigated sections.

Alfalfa, in cultivated rows and broadcast, has been tried for seed on the Station, but the yield of seed has been too low and too uncertain to justify recommending the crop as a profitable one to grow for seed on a commercial basis.

## SUMMARY

Wheat is the most important farm crop grown in Eastern Oregon. It was first raised in Umatilla county about 1870, and the acreage devoted to the crop has gradually increased until nearly all cultivable dry farm land in Eastern Oregon is now devoted to wheat raising.

The substitution of suitable crop rotations to replace the present practice of growing wheat after fallow would be desirable because it would mean less trouble in maintaining soil fertility, better distribution of farm labor, the increasing of total farm output, and the reduction of crop risks and hazards of low prices.

Some of the difficulties in the way of practicing crop rotations in this region are low annual precipitation, lack of crops as productive as small grains, and scarcity of grazing land for livestock raising.

The annual precipitation in Eastern Oregon ranges from nine to twenty inches, most of which comes during the months of September to June, inclusive. Where the precipitation is from nine to twelve inches, it is usually necessary to fallow in order to get enough moisture in the soil to grow a crop to maturity. Where the annual precipitation exceeds twelve inches, the soil in the early spring may frequently contain its maximum field-carrying capacity of soil moisture irrespective of previous cropping or cultivation. The average percentage of moisture in the soil to a depth of six feet in early April at Moro for the five years, 1919 to 1923, inclusive, was 14 percent after fallow, 13.8 percent after peas, 12.4 percent after corn, 12.7 percent after spring wheat, and 12.2 percent after winter wheat. The average precipitation of the crop year, September 1 to August 31, for the same five-year period was 11.5 inches.

Crop rotation experiments were begun on the Branch Experiment Station at Moro in 1911. Five rotations on land alternately cropped and fallowed have been continued since 1912. Of the grain crops grown after fallow, spring barley produced the highest average annual seed yield, 988.8 pounds per acre, winter wheat second with 870 pounds per acre, spring oats third with 801.6 pounds per acre, and spring wheat fourth with 714 pounds per acre.

Rotations which included a summer fallow once in three years and once in four years did not on the whole produce as high annual yields of grain as alternating spring barley or winter wheat with summer fallow.

The following rotations have produced higher average annual seed yields per acre than the standard rotation, winter wheat—fallow, which produced an average annual yield of 870 pounds per acre:

| | Average annual seed yield per acre |
|---|---|
| | *lbs.* |
| Spring wheat—barley—potatoes | 1168.8* |
| Spring wheat—corn—barley | 1119.9 |
| Spring wheat—peas | 1053.0 |
| Spring wheat—barley—corn | 996.9 |
| Oats—barley—peas turned under—corn | 994.6 |
| Spring barley—fallow | 988.8 |
| Spring wheat—barley—manured fallow—corn | 988.8 |
| Corn continuously | 963.2 |
| Winter wheat—potatoes—winter wheat—fallow | 914.0* |
| Spring wheat—barley—fallow—corn | 907.8 |
| Winter wheat—peas—winter wheat—fallow | 883.5 |
| Spring barley—spring barley—fallow | 876.8 |

*Potato yields not included.

The cost of production and the value of various crops grown in the rotation experiments are given on pages 27 to 32. Table IX shows the average acre yield of each rotation, the cost of producing the crop, and the annual profit or loss on each crop and on each rotation. According to the figures used, the most profitable rotations that have been in progress at Moro have been the following:

| | | Annual profit per acre on rotation |
|---|---|---|
| 1E. | Potatoes—fallow | $7.34 |
| 19. | Peas continuously | 5.65 |
| 21. | Spring wheat—peas | 5.59 |
| 9. | Spring wheat—corn—barley | 3.75 |
| 1A. | Winter wheat—fallow | 3.47 |
| 22. | Winter wheat—peas—winter wheat—fallow | 3.25 |
| 27. | Winter wheat—peas—peas | 3.02 |
| 1C. | Spring barley—fallow | 2.80 |

Discussion of the various crops best suited for growing in dry-land crop rotations is given on pages 32 to 43.

Winter wheat will likely always remain the leading dry-land crop in Eastern Oregon because of its high yield when grown after fallow and because of its advantages in farm labor distribution.

Spring wheat proved slightly superior to winter wheat in crop rotations without summer fallow. The yields of spring wheat sown after corn, peas, and potatoes, were a little higher than the yields of winter wheat after these crops though when sown after fallow, spring wheat was outyielded by winter wheat.

Barley, which is the standard feed crop in Eastern Oregon, produced more pounds per acre than winter wheat when grown after fallow. This crop is admirably adapted to most Eastern Oregon soils and should have a prominent place in any rotation involving spring-sown grains.

Oats did not produce as high yields as barley when grown after fallow or when grown after corn in the rotation experiments.

Corn in various rotations produced average yields of from ten to twenty bushels per acre, with stover yields of about 1.5 tons per acre.

For Eastern Oregon dry lands, corn will probably prove profitable only when utilized for pasture or silage. Winter wheat yields after corn averaged about nine bushels an acre less than after fallow. Spring wheat yields after corn averaged about three bushels less than after fallow. Yields of oats and barley after corn also were not so high as when grown after fallow. Reduction in seed yields of small grains grown after corn are partly compensated by the lower expense of seed-bed preparation.

Field peas after cereals at Moro averaged about ten bushels per acre when grown in cultivated rows. The chief value of this crop also lies in its use for pasture purposes. Winter wheat and spring wheat averaged about two bushels per acre more after peas than after corn, but less than after fallow. As in the case of corn, seed-bed preparation for cereals grown after peas is less expensive than when cereals are grown after fallow.

Potatoes have proved profitable only when grown after fallow at Moro. When grown after grain, yields are low, with high percentages of unmarketable tubers.

Alfalfa has not been included in any of the regular rotations, but the crop has been thoroughly tested at Moro and on the average has not proved profitable. When grown in cultivated rows, hay yields of from 1.0 to 1.5 tons per acre were obtained. Reduced yields of cereals were obtained for two seasons following alfalfa even when the alfalfa was followed by a season of fallow. Alfalfa, in cultivated rows or broadcast for seed production, has not proved profitable at Moro.

Station Bulletin 210 October, 1924

Oregon Agricultural College

Experiment Station

Soils Department

# A Progress Report of Alkali Land Reclamation Investigations in Eastern Oregon

By

W. W. Johnston and W. L. Powers

1885

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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# SUMMARY

1. Herein is reported the progress of four seasons' field and tank experiments with natural "black alkali" land which is only slowly permeable to water.

2. A method of sluicing deep drainage ditches developed as a result of experiments in this connection has made it possible for farmers, under favorable conditions, to secure drainage cheaply.

3. Leaching alone has been effective in removing the neutral salts but has not been effective in removing the sodium carbonate or in improving the physical condition. Leaching and drainage in connection with chemical treatments have been found necessary in order to remove the neutral salts resulting from the decomposition of sodium carbonate.

4. Seven to ten tons of gypsum per acre have been required to neutralize the sodium carbonate sufficiently to secure a good stand of sweet clover.

5. The application of 500 pounds of sulfur with 20 tons of manure per acre made it possible to secure a fair yield of rye and a good stand of sweet clover. Studies indicate that heavier applications of sulfur alone will be effective. The effect of combinations of sulfur with quicklime, with gypsum and with manure is being investigated.

6. Five tons of aluminum sulfate have been required to soften the soil. Lighter applications have been ineffective.

7. Manure has been effective when in combination with sulfur and gypsum, but not when used alone.

8. Getting uncleared, drained "grease wood land" into pasture and using frequent irrigations has proved to be an economical method of utilizing the hard alkali lands of Malheur county and affords partial reclamation.

9. Tank experiments have verified field results and show the value of heavy gypsum, sulfur, and alum treatments.

# A Progress Report of Alkali Land Reclamation Investigations in Eastern Oregon

By

W. W. Johnston and W. L. Powers

## INTRODUCTION

It has been estimated that from 12 to 15 percent of the land under irrigation ditches in the United States is limited in production to a greater or less extent by alkali. In Oregon a few projects are practically free from alkali troubles, but most of the projects are somewhat affected and on a few the majority of the lands included are affected to a greater or less degree. There is in Oregon perhaps 75,000 to 100,000 acres of land so affected offering possibilities for reclamation.

Alkali difficulties are generally associated by most irrigation farmers with a water-logged condition of the soil, which results in the accumulation of soluble salts throughout the soil mass at or near the surface as the result of evaporation of water brought up by capillarity from the high water-table. This condition usually exists on soils that are readily permeable to water, and the reclamation of such land is generally accomplished by providing drainage to lower the water-table and by washing out the salts by means of heavy irrigations. This represents our "white alkali" problem or the problem of reclaimed lands that have become affected with soluble chlorids and sulfates of sodium, magnesium, and potassium, and where the land is permeable to water. Such lands are more aptly termed "saline soils."

In addition to these saline soils, we have thousands of acres of so called "black alkali land." The reclamation of this type of soil presents a problem that is much more difficult and very different from that of the white alkali land. These soils are characterized by a high percentage of sodium carbonate and by their poor physical condition, the surface being easily puddled and the entire soil mass partly or nearly impermeable to water. Scofield and Headley,[1] and other investigators[2, 3] have published data showing that this condition is probably due to the substitution of alkaline bases, largely sodium, for some of the earthy bases such as calcium in the finer soil material. This results in a soil of different characteristics, which is less permeable to water, shows a deflocculated condition, and becomes very hard upon drying out. They have shown that this condition may be developed upon leaching the soluble salts from a saline soil, particularly where the replacable calcium content is low as compared to the content of replacable or very slightly soluble sodium and where the soil contains considerable clay. Soluble salts are continually being liberated as soil forming minerals are weathered, but in humid sections the excess of salts is removed in drainage water to the ocean. Irrigation water carrying considerable quantities of sodium salts is objectionable.

True alkalinity is to be distinguished from salinity. The latter condition is one in which neutral salts like sodium sulfate, or sodium chlorid are in solution, and in high concentration this may interfere with the absorption of plant nutrients. True alkalinity obtains where hydrolizable salts give rise to a concentration of OH ions greater than in pure water. Pure water as $H_2O$ or HOH dissociates to a slight extent into hydrogen ions ($H+$) and hydroxyl ions ($OH-$). The hydrogen ions are bitter and give rise to acids and soil acidity. Hydroxyl ions give rise to true alkalinity. Sodium unites with the hydroxyl ion readily to form sodium hydroxide or caustic soda. It may then combine with the finer soil material to form jelly-like compounds causing deflocculation of the soil and consequent impermeability. This gives rise to an excess of OH ions, which are more toxic to plants than hydrogen ions. This puddled alkaline condition interferes with plant nutrition in several ways. It may interfere with root development, germination, bacterial activity, and absorption of plant nutrients. A high concentration of OH ions will cause iron and phosphorus to disappear partly from the soil solution.

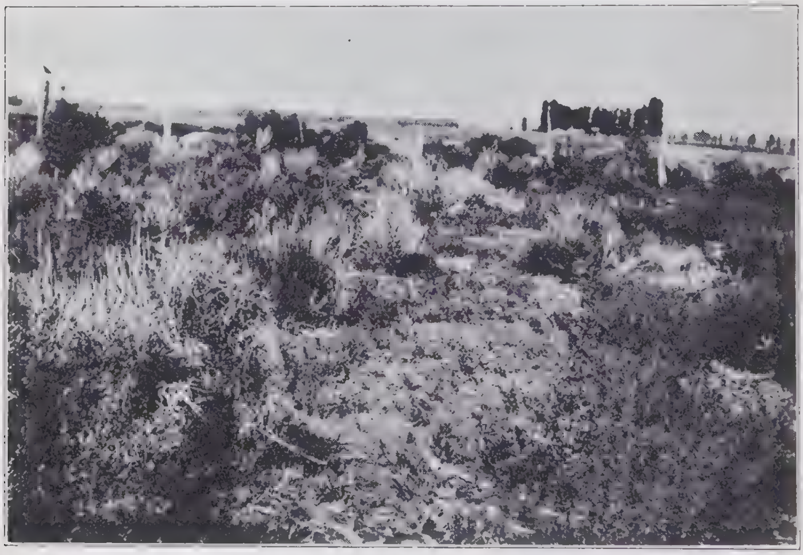

Fig. 1. Native vegetation. Land used for pasture experiment with uncleared land. Note grease wood, salt grass, and small amount of sagebrush.

In order to correct these difficulties in arid soils drainage and leaching are used to remove the soluble salts, while chemical treatment is effective in converting the replacable sodium compound to soluble form and in improving the reaction and tilth so that this soluble material can be leached out. Sulfates and carbon dioxide from the decay of organic matter or excretion by plant roots tend to neutralize the soil. Light, temperature, and humidity are other factors to be considered.

It is certain that we have considerable areas of land that have once been very productive, which have later become saline and finally have turned into black alkali land. In addition to this, we have large areas of so called "grease wood" (*Atriplex nuttellii* S. Wats) land, most of which is unproductive in the virgin state, or has become infertile while still in the virgin state where the total salt content is fairly low, the sodium carbonate content high, and the soil very impermeable to water.

This last type of land is recognized as being very difficult to reclaim, and it is doubtful if reclamation should be undertaken were it not for the fact that thousands of acres of such lands are included in existing projects located under existing ditches and against which lands water-right charges are assessed. The development of a method of reclaiming or utilizing this type of alkali land is one of the important soil problems and is the problem dealt with herein.

Experiments were undertaken in the spring of 1921 by the Soils department of the Experiment Station on a tract of grease wood land near Vale, Oregon. The land was drained, cleared, leveled, diked for flooding, and chemically treated for the purpose of studying this problem. Tank trials have been conducted in the greenhouse, and numerous laboratory tests and several hundred alkali determinations have been made to check the field work. While the results are still incomplete, it is the purpose of this bulletin to report the findings and the progress made to date.

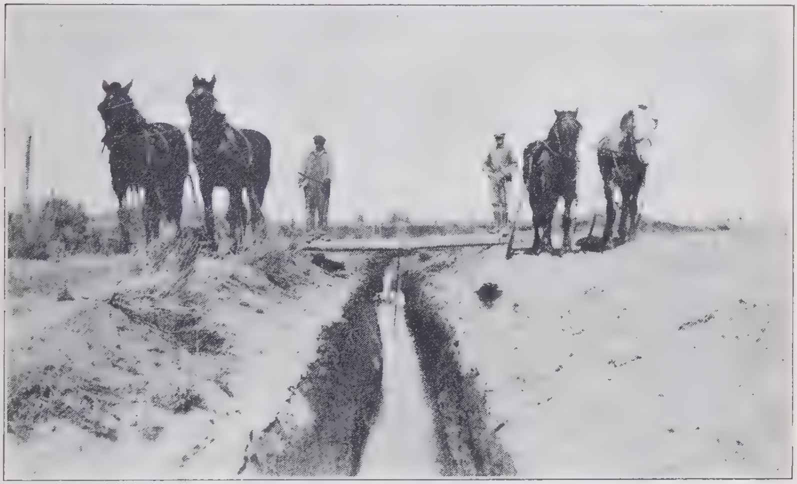

Fig. 2. Sluicing with the "Purvis sluicer." Two men and teams, a twenty-five dollar machine, and a head of water build cheap drainage ditches. A good fall, a head of water (3 to 4 second feet), and a soil that is loose enough to plow and fine enough to go into suspension with water are the conditions necessary for success with this method.

## FIELD TRIALS

The upper Malheur Valley, in which the ten-acre alkali experiment field is located, is of an alluvial formation. The slope of the Valley floor with the river is very good and in the region of the experiment field there is considerable fall across the Valley in the direction of the river. The grease wood lands are found running parallel to the river, including the lower part of the old Valley filling soil. This strip varies from one-eighth of a mile to a mile or more in width, being wider where the Valley is wide. Part of this land is water-logged, but in other localities, particularly in the locality where the experiment field is located, the water-table does not come closer than 6 to 7 feet from the surface. This area is found to contain, near the lower edge, a series of hard-pan dikes, which run parallel to the river and extend from within a foot or two of the surface to a depth of from 8 to 12 feet where they connect with a putty-like clay through which water will seep but slowly. This condition has not held up drainage entirely, but has impeded it to such an extent that the water-table has been high during a certain part of each year as a result of heavy irrigation of the land at higher elevations. Evidently alkaline salts have been brought down with the drainage water and a portion has been left each year, with the result that sodium salts have accumulated and the soil has been changed to its present condition. The land in these grease wood strips is worse in the portion near but not adjacent to the river, having a higher black alkali content, and being more impermeable to water.

The experiment field is located in the latter type of grease wood land and represents the worst type of black alkali land in the Malheur Valley. The soil is heavy loam, and most of the field is underlaid with a streak of hard-pan at from 3 to 4 feet from the surface. Sand is generally encountered at about 8 feet and gravel at 13 feet.

## CHEAP DRAINAGE PROVIDED BY SLUICING

It is well known that in any sort of alkali land reclamation drainage is necessary in order to provide an outlet for washing out the natural saline salts in the soil and in the case of soils containing sodium carbonate to remove the neutral salts resulting from the decomposition of this compound by chemical treatment. When the natural drainage is insufficient to take care of the heavy irrigations used in leaching, artificial drainage must be provided. The cost of providing such drainage has an important bearing on the feasibility of reclaiming alkali land.

In an attempt to meet the need for a cheaper method of drainage an experiment was conducted in the spring of 1921 to determine the feasibility of adapting the sluicing method of moving earth to the constructing of deep drainage ditches. This method consists of running a head of water through a shallow ditch and deepening it by stirring the earth in the bottom by some means and washing it out with the water. A ditch was constructed by this means on the field to be used for the alkali experiments. In its construction a number of methods were employed for loosening the earth and keeping it in suspension. A long iron bar, a cultivator, and a shovel were all used, the larger part of the excavation being accomplished by loosening the earth with an ordinary irrigation shovel and allowing the water to carry it out. This was done while the water was running, a head of about four second feet being used. The one-horse cultivator was found to be especially efficient but was rather hard to handle. This tool was operated by attaching it with a long chain to the middle of a pole which extended across the ditch. A horse was hitched to each end of the pole and the machine dragged up and down the ditch. This ditch, which averaged 12 feet in depth, cost 20 cents per foot of ditch and about 11 cents per yard of earth removed.

### The Purvis Sluicer

The work of the Station showed a need for some sort of tool which could be operated by horse-power and which would not require a man in the ditch for its operation. Such a tool has been invented by Mr. Percy Purvis of Vale, and is known as the "Purvis sluicer." This machine is cylindrical in shape, and its cutting power is derived from cylinder teeth which protrude at intervals from the entire exterior area. In operating, the machine is dragged up and down the ditch lengthwise, the same method being employed as that described for the cultivator. The machine is made entirely of iron and can be constructed by any good blacksmith. It costs about $25.00.

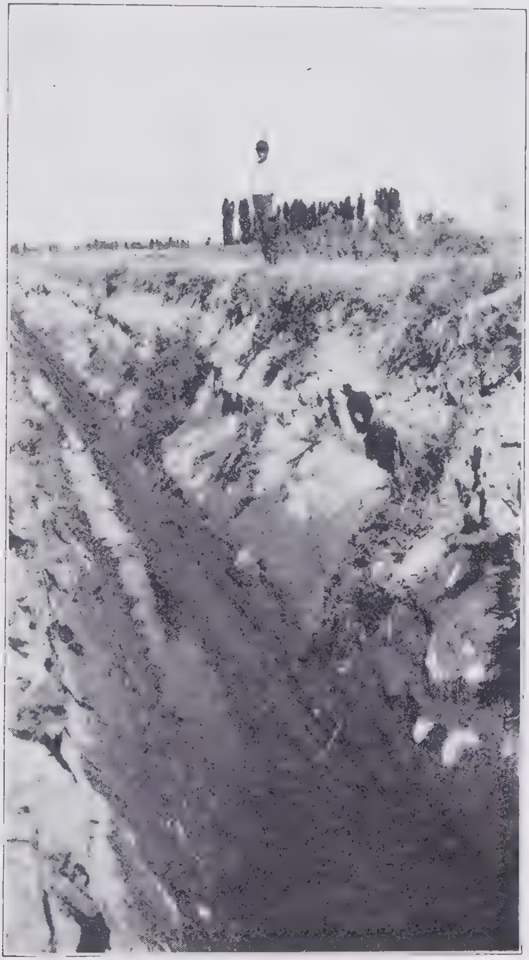

Fig. 3. The finished drain. Open ditch twelve feet deep built by sluicing at a cost of seventeen cents per foot of drain. The banks cave in each year as far back as frozen. This earth is sluiced out in the spring. In three years a slope of one to one is secured, and after this but little caving occurs.

### Cost of Building Ditches with Water

This method is not applicable to all conditions, but where a deep outlet is available, where the land has a fall of eight feet per mile or more, and the soil is of such nature that it can be readily plowed, the use of this method has provided very cheap drainage. The cost of sluicing a ditch under ideal conditions is well illustrated by referring to one constructed near Vale, Oregon, by Messrs. Russell, Carmen, and Hadley. This drain was built with the Purvis sluicer and is 2,225 feet long, averaging 12 feet in depth, and cost, when all labor charges were considered, $247.00. This amounts to eleven cents per foot of drain or five cents per cubic yard of earth removed. The cost exclusive of labor was less than $50.00. This ditch is estimated by its owners to affect about 100 acres of land. The sluicer has been successfully used on the Ochoco Project and the Grants Pass section, where ditches have been constructed at one-half the cost required by former methods.

## ALKALI IN SOILS

In Table I is reported the average alkali content calculated as sodium chlorid, sodium sulfate, and sodium carbonate.

The determinations were made from a 1:2.5 solution with water, and the alkali, reported as sodium carbonate, represents the result of titrating with N/.1 normal hydrochloric acid, using methyl orange as an indicator, and is taken to represent, at least comparatively, the effective alkalinity of the soil.

TABLE I. ALKALI CONTENT, VALE EXPERIMENT FIELD

| | | Alkali content parts per million | | |
|---|---|---|---|---|
| Depth of sample | Total salts by dessication | Carbonates expressed as sodium carbonate | Chlorides expressed as sodium chlorid | Sulfates expressed as sodium sulfate (by difference) |
| 0′ — 1′ | 7350 | 1629 | 639 | 4082 |
| 1′ — 2′ | 7700 | 1563 | 705 | 5432 |
| 2′ — 3′ | 5205 | 1143 | 513 | 3549 |
| 3′ — 5′ | 4052 | 850 | 418 | 2784 |
| 5′ — 7′ | 1463 | 441 | 243 | 779 |

Note: These figures each represent the average of 14 analyses, each analysis being made from a composite of 3 samples.

It will be seen that the alkali is fairly well distributed through the first three feet of soil, and that while it diminishes at the lower depth, considerable is yet to be found in the sixth and seventh foot.

The area was drained, cleared, and leveled in the spring of 1921, and plots laid out to compare the effect of various treatments of gypsum, sulfur, aluminum sulfate, manure, and certain combinations of these treatments, all combined with drainage and flushing with heavy irrigations to wash out the soluble salts.

### Effect of Leaching

During the first three seasons of the experiment all plots were irrigated uniformly. During the first season a little over three and one-half acre feet per acre was used and in the next two seasons a somewhat smaller amount was applied. The soil takes up water very slowly. A four-inch irrigation applied and held on the land will not disappear until forty-eight to fifty-two hours after its application, and considerable of this loss, of course, is due to evaporation. As stated, all plots were uniformly leached whether chemically treated or not, and the effect of leaching, without the aid of other treatment, can be determined by a study of check plots D, E, and I.

Table IIa gives the results of the analysis of samples taken from the various plots in the spring of 1921, when the experiment was started, and

### TABLE IIa. ALKALI RECLAMATION TRIALS

Parts per Million of Alkali in Surface foot 1921-1923
(Expressed as salts of sodium)

| | | Spring 1921—Initial | | | | Fall 1923 | | | |
|---|---|---|---|---|---|---|---|---|---|
| Plot | Treatment | P.P.M. Total salts | P.P.M. $Na_2Co_3$ | P.P.M. NaCl | P.P.M. $Na_2So_4$ | P.P.M. Total salts | P.P.M. $Na_2Co_3$ | P.P.M. NaCl | P.P.M. $Na_2So_4$ |
| A | Manure 20 T. | 7147 | 1443 | 378 | 5326 | 3450 | 1006 | 490 | 1954 |
| B | Check | 4810 | 444 | 126 | 4240 | 1150 | 672 | 175 | 303 |
| C | Sulfur 500 lbs.<br>Manure 20 T | 9918 | 1554 | 630 | 7734 | 4680 | 564 | 129 | 3987 |
| D | Gypsum 1200 lbs.<br>Manure 20 T | 7853 | 1443 | 378 | 6032 | 2820 | 1022 | 824 | 974 |
| E | Check | 7969 | 2442 | 378 | 5149 | 3800 | 1022 | 176 | 2602 |
| F | Green Manure | 10530 | 2886 | 756 | 6888 | 2370 | 1839 | 220 | 311 |
| G | Sulfur 500 | 7818 | 2442 | 1386 | 3990 | 2410 | 635 | 1550 | 225 |
| H | Sulfur 1000 | 7006 | 1222 | 756 | 5028 | 2380 | 1379 | 499 | 502 |
| I | Check | 5370 | 1776 | 882 | 2722 | 2140 | 1622 | 292 | 226 |
| J | Gypsum 800 lbs. Increased Fall '22 to 20400 lbs. | 6632 | 1110 | 252 | 5270 | 2450 | 1450 | 456 | 544 |
| K | Gypsum 1600 lbs. Increased Fall '22 to 13600 lbs. | 8629 | 2442 | 630 | 5557 | 2600 | 490 | 447 | 1663 |
| | Gypsum 2400 lbs. Increased Fall '22 to 6800 lbs. | 6728 | 1887 | 630 | 4211 | 1450 | 954 | 152 | 344 |
| | Average | 7534 | 1758 | 597 | 5179 | 2641 | 1055 | 450 | 1036 |

### TABLE IIb. ALKALI RECLAMATION TRIALS

Parts per Million of Alkali — Average Surface 3 Feet
(Expressed as salts of sodium)
(1921-1923)

| | | Spring 1921 — Initial | | | | Fall 1923 | | | |
|---|---|---|---|---|---|---|---|---|---|
| Plot | Treatment | P.P.M. Total salts | P.P.M. $Na_2Co_3$ | P.P.M. NaCl | P.P.M. $Na_2 So_4$ | P.P.M. Total salts | P.P.M. $Na_2Co_3$ | P.P.M. NaCl | P.P.M. $Na_2 So_4$ |
| A | Manure 20 T. | 6404 | 1110 | 264 | 5030 | 2187 | 698 | 275 | 1217 |
| B | Check | 5634 | 592 | 168 | 4874 | 1913 | 625 | 342 | 946 |
| C | Sulfur 500 lbs.<br>Manure 20 T | 11484 | 1517 | 1134 | 8833 | 3993 | 683 | 202 | 3108 |
| D | Gypsum 1200 lbs.<br>Manure 20 T | 7668 | 1591 | 378 | 5699 | 4693 | 1752 | 847 | 2094 |
| E | Check | 6700 | 2072 | 504 | 4124 | 2340 | 1034 | 262 | 1044 |
| F | Green manure | 9155 | 1961 | 1134 | 6060 | 3847 | 1734 | 905 | 1208 |
| G | Sulfur 500 | 5387 | 1591 | 882 | 2914 | 2823 | 1415 | 979 | 429 |
| H | Sulfur 1000 | 5711 | 705 | 714 | 4292 | 2343 | 1343 | 652 | 348 |
| I | Check | 4737 | 1591 | 672 | 2474 | 3600 | 1471 | 346 | 1783 |
| J | Gypsum 800 lbs. Increased Fall '22 to 20400 lbs. | 7791 | 1147 | 420 | 6224 | 4353 | 1730 | 779 | 1844 |
| K | Gypsum 1600 lbs. Increased Fall '22 to 13600 lbs. | 9356 | 1924 | 756 | 6676 | 4240 | 894 | 379 | 2967 |
| L | Gypsum 2100 lbs. Increased Fall '22 to 6800 lbs. | 6036 | 1517 | 420 | 4099 | 6600 | 1238 | 156 | 5216 |
| | Average | 7172 | 1444 | 620 | 5108 | 3577 | 1217 | 511 | 1849 |

TABLE III. CHEMICAL COMPOSITION OF SOIL

| | April, 1921 sample | September, 1921 sample |
|---|---|---|
| $K_2O$ | 2.450 | 2.360 |
| CaO | 3.450 | 3.620 |
| MgO | 1.080 | 1.170 |
| $P_2O_5$ | .242 | .237 |
| S | .041 | .028 |
| N | .040 | .034 |

Soluble calcium, composite sample, 1921, .0147.
Analysis by Station Chemist, J. S. Jones.

again in the fall of 1923 for the surface foot, and Table IIb gives the average results for the surface three feet. Each sample is a composite from three borings, borings being made from the same location in each plot whenever sampled. It will be noted that plots B, E, and I, which were provided with drainage and heavy irrigation but with no chemical treatment, showed a much lower total alkali content after three years' treatment. The sodium carbonate content, however, has not been consistently reduced and in fact, in one or two cases it appears to have increased. These plots have not shown any improvement in physical condition or in permeability, and while it is now possible to get seed to germinate in the surface soil of these plots, no crops have been produced upon them. The only place where leaching without chemical treatment in addition has been effective is where the land has been uncleared and handled for the purpose of securing pasture, a discussion of which is taken up in a later section.

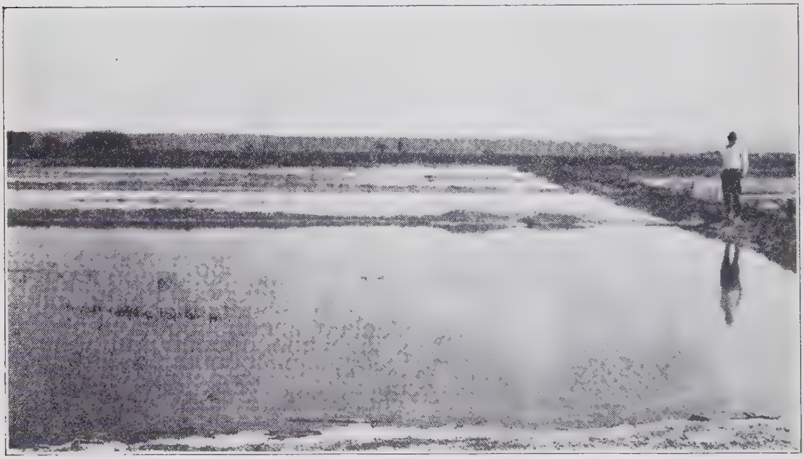

Fig. 4. Flooding to leach sulfur plots. It has been possible to remove the saline salts by leaching after drainage has been provided. The land takes up water slowly but will leach through if held on the land long enough.

### Effect of Leaching on Plant Nutrients (Table III)

In order to obtain some evidence of the general fertility of this soil and to learn the effect of extensive leaching on fertility, composite samples from the surface foot when the experiment was started, and again after a year's treatment were analyzed by Station Chemist J. S. Jones. Results of analysis are found in Table III. It will be noted that the sulfur and nitrogen content has been reduced somewhat, but that otherwise the leaching has had little effect upon the fertility elements. This soil was found to contain ample amounts of mineral nutrient elements. Leaching has the effect of softening up the hard-pan so that this layer is now but little harder than the rest of the soil, and it has been effective on all plots in removing the neutral salts. Ammonium sulfate applications have not benefited subsequent crops.

The discharge of the drainage ditch has been measured and samples have been taken for analysis. The results of these tests indicate that some 150 tons of alkaline salts have been removed in the drainage water. Not all of this has come from the land in the experiments, but the indications are that a large part of it has come from this source, as but little other land is irrigated in the vicinity, and the flow of water in the drain diminishes markedly when irrigation has ceased on the plots for a few days.

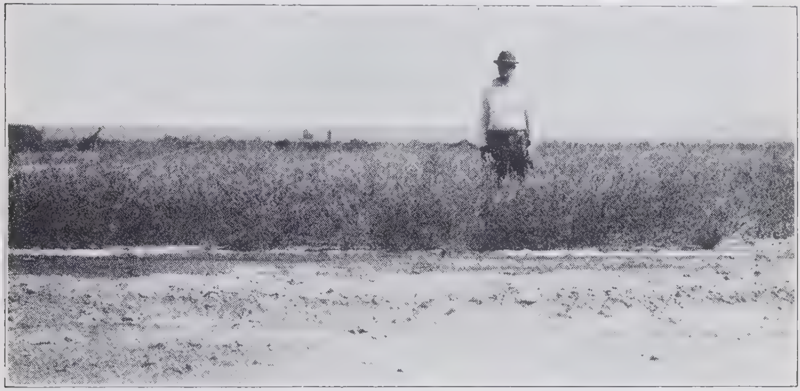

Fig. 5. White sweet clover *(Melilotus alba)* on gypsum plot. This plot was treated with gypsum at the rate of 10.2 tons per acre. On an adjoining check plot which received identical treatment with the exception of the gypsum application, no stand was secured.

## Effect of Calcium Sulfate (Gypsum)

Calcium sulfate (gypsum) has been used in various amounts in the Oregon experiments. When the experiment was started, plots J, K, and L were treated with gypsum at the rates of 400, 800, and 1,200 pounds per acre respectively. The next season these plots were retreated with the same amount, bringing the treatments up to 800, 1,600, and 2,400 pounds per acre. No marked benefits were observed from these treatments. On plot L, which received the heaviest treatment, the soil became somewhat more mellow in the surface inch or two, but the chemical analysis did not indicate that much sodium carbonate had been removed, and the land still remained unproductive. In the fall of 1922 the center one-third of each of these plots was retreated to bring the total amount of gypsum applied to 3.4, 6.8, and 10.2 tons per acre respectively, amounts sufficient theoretically to combine with one-half of the sodium carbonate in the water extract in plot J, enough to combine with all the carbonate in plot K and twice the amount theoretically required to neutralize the sodium carbonate in plot L.

All plots were seeded in the fall of 1922 to rye, and reference to Table IV will show that while the yield of rye hay on plots J, K, and L was very low, it exceeded that of the adjoining check by a large amount. Plot L yielded at the rate of 810 pounds per acre, while plot I, which was untreated, yielded 200 pounds per acre.

In the fall of 1923 all plots were seeded to sweet clover, the crop being irrigated by using corrugations and leaving the water on for several days. The stands obtained on the gypsum plots were decidedly bet-

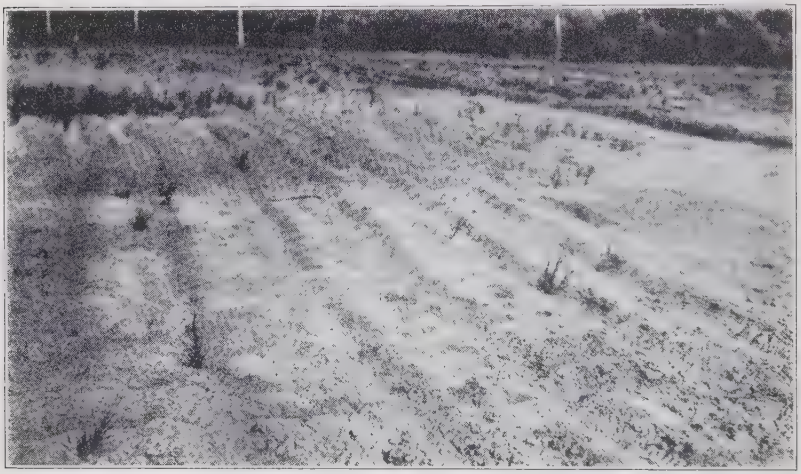

Fig. 6. Soil structure improved by gypsum treatment. Note the improved soil condition and also the white alkali showing up as a result of the treatment. This can be removed by leaching.

TABLE IV. ALKALI RECLAMATION EXPERIMENTS,
YIELD OF RYE HAY 1923

| Plot | Treatment | Yield per acre | Sweet clover seeded 8-25-24, results as follows |
|---|---|---|---|
| A | Manure 20 T. | 202 | No stand |
| B | Check | 0 | No stand |
| C | Sulfur 500 lbs.<br>Manure 20 T. | 2020 | Fair stand from spring seeding |
| D | Gypsum 1200 lbs.<br>Manure 20 T. | 1700 | Fair stand from spring seeding |
| E | Check | 166 | No stand |
| F | Green manure | 154 | No stand |
| G | Sulfur 500 | 350 | Slight stand on upper part |
| H | Sulfur 1000 | 650 | No stand |
| I | Check | 200 | No stand |
| J | Gypsum 800 lbs.<br>Increased Fall '22<br>to 6800 lbs. | 545 | Scattering stand |
| K | Gypsum 1600 lbs.<br>Increased Fall '22<br>to 13600 lbs. | 550 | Good stand |
| L | Gypsum 2400 lbs.<br>Increased Fall '22<br>to 20400 lbs. | 810 | Excellent stand—thrifty plants |

ter than in any other part of the field, and there was a great deal of variation between these, a fair stand being secured on plot J, a good stand on plot K, and an excellent stand on plot L. The scattering stand on plot J did not live throughout the winter, but plots K and L produced in the summer of 1924 a good crop of sweet clover, the growth being more rank and more uniform in plot K. Its appearance on August 5, 1924, is shown in Fig. 5.

The improvement in the physical condition of the soil, as the result of gypsum treatment, is very apparent. The soil is softer than on the untreated plots, does not run together so badly after irrigation, and absorbs the irrigation water more quickly. The difference is especially marked on plot L, which has received 10.2 tons gypsum per acre. On this plot the moisture spread well between corrugations, and the soil did not dry out as quickly as it did where untreated. Reference to Table II shows that the analyses of samples from these plots indicate that the sodium carbonate has been reduced considerably as a result of this treatment, except with the lightest application, plot J.

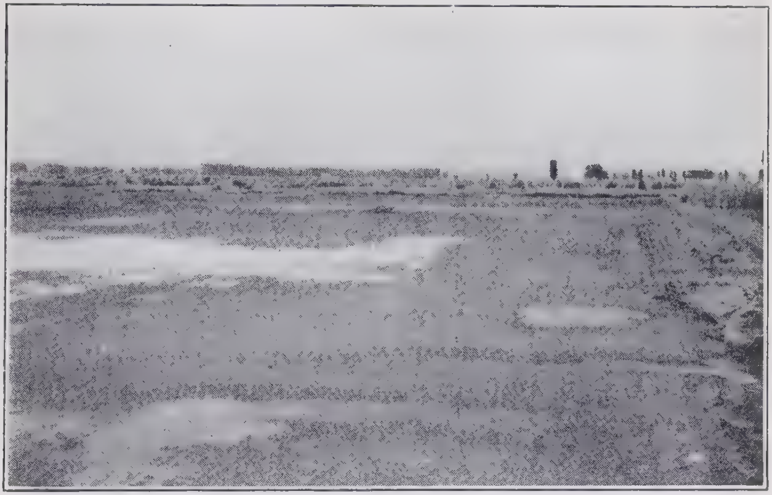

Fig. 7. Grease wood land, Vale, Oregon. Rye failed after drainage and with no chemical treatment.

These results indicate that at least from 7 to 10 tons of gypsum in connection with drainage and leaching will be required to improve this soil to an extent that profitable crops can be grown. Gypsum has been applied on this land in pounds per acre as follows: 400, 800, 1200, 1600, 2000, 2400, 4000, 6800, 13600, 20400. No substantial benefits have been noted in any applications under 6800 pounds, when applied alone.

Plot D was treated in 1921 with twenty tons of manure, combined with 600 pounds of gypsum per acre, and was retreated with the same amount the next spring.

Reference to Table IV will show that this plot yielded rye hay in the fall of 1923 at the rate of 1700 pounds per acre, while the adjoining check yielded but 166 pounds per acre. A fair stand of sweet clover was secured from the spring seeding, while no stand was secured on the adjoining check. Manure alone on plot A, although applied in the same manner and in the same amount, resulted in very little improvement as determined either by the crops raised or by the results of chemical analysis. The yield of rye hay on plot A was 202 pounds per acre, and no growth of sweet clover was secured. It is thought that the benefit from this small amount of gypsum combined with the manure treatment was largely temporary, due probably to the effect of carbon dioxide resulting from the decay of the manure, combined with the flocculating effect of the gypsum on the surface soil. The sweet clover lived into the summer of 1924 but did not grow vigorously, yielding only a small amount of pasture.

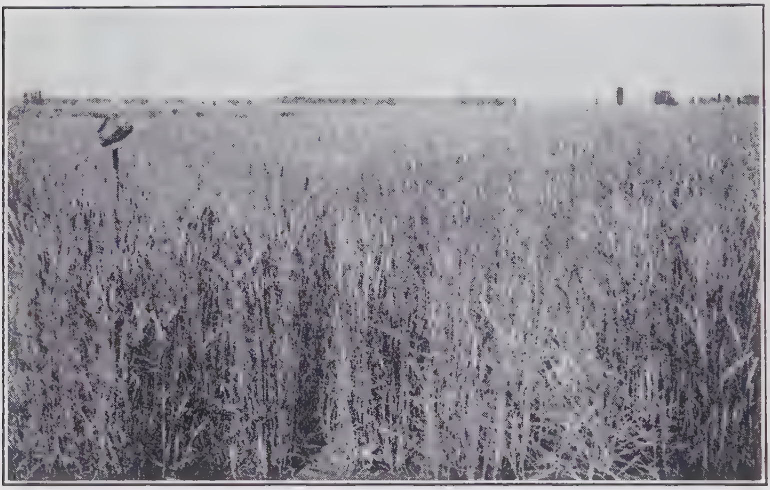

Fig. 8. Grease wood land, Vale, Oregon. Received sulfur costing $8 an acre and manure and yielded one ton of rye hay per acre after drainage and flushing.

## Effect of Sulfur

In connection with his work on sulfofication, J. G. Lipman[4] suggested that sulfur might be effective in decomposing sodium carbonate in soil. Elemental sulfur when applied to the soil is oxidized by biological activity mainly, and combines with water to form sulfuric acid, an acid which actively combines with basic materials in the soil. Investigators[1, 2] have pointed out that applications of sulfur resulted in the decomposition of sodium carbonate, and also that it probably combines with the complex sodium silicates, which are held to contribute markedly to the impermeable conditions of black alkali soils. When the soil is low in calcium it is very likely that this material, or some similar base, will be needed in addition to the sulfur to effect the proper exchange of bases with the sodium-containing soil substance, and for the return of a flocculated soil condition. When the calcium content is good, however, it is very probable that this end can be obtained by the use of sulfur alone.

Prior to the spring of 1924, sulfur had been used in the Oregon experiments in amounts from 250 to 1000 pounds per acre. While chemical studies have indicated that it has helped to neutralize the alkalinity, the treatments have not resulted in the soil becoming productive when sulfur has been used alone. When in combination with 20 tons of manure, the use of 500 pounds of sulfur per acre resulted in a yield of over one ton of rye hay per acre in the fall of 1923. Sulfur-oxidizing bacteria were probably more active where manure was added. Reference to Table II will show that this plot (plot C) was benefited considerably by the reduction of sodium carbonate.

The preliminary results with sulfur indicated that insufficient amounts had been used, and in order to gain information on this point, three of the tanks of alkali soil which are described in another section of this report were treated with heavier sulfur applications. All three tanks had been heavily leached. Tank 1 had received no chemical treatment, while tanks 5 and 6 had been treated with sulfur in October, 1922. The original treatments and new applications, together with the alkali content of No. 1 before the new applications were made and of each of the three six weeks after treating, are given in Table V.

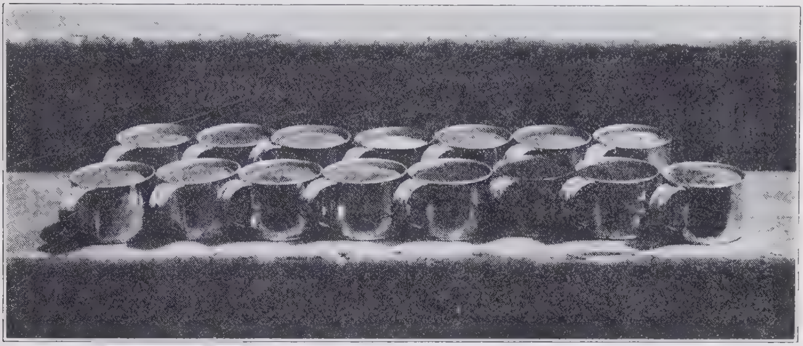

Fig. 9. Samples used for crushing tests. Samples treated with organic matter, gypsum, or aluminum sulfate, crumbled more readily after baking, indicating an improvement in the physical condition.

TABLE V. THE EFFECT OF SULFUR TREATMENTS ON THE ALKALI CONTENT OF SOIL IN TANKS

| Treatment | Pounds per acre 10-25-22 | 1-4-24 | P.P.M. Alkali (expressed as salts of sodium) Total salts | $Na_2CO_3$ | NaCl | $Na_2SO_4$ |
|---|---|---|---|---|---|---|
| 1 Ck before treatment | 0 | ------- | 2050 | 847 | 117 | 1096 |
| Six weeks after treating. | | | | | | |
| 1. Sulfur | 0 | 1000 | 2710 | 429 | 154 | 2127 |
| 5. Sulfur | 1000 | 3000 | 3064 | 195 | 116 | 2753 |
| 6. Sulfur | 500 | 500 | 1462 | 225 | 132 | 1105 |

The time allowed for the oxidation of the sulfur and for the resultant action with the soil constituents was probably too short for the action to be complete. These data, however, indicated that the previous field applications were too light to be effective.

In the spring of 1924, the three one-half-acre sulfur plots were divided lengthwise to make six quarter-acre plots and treatments were increased to give plot G-1 1,000 pounds per acre, plot G-2 2,000 pounds per acre, plot H-2 4,000 pounds per acre, and plot H-1 4,000 pounds of sulfur, with one-fifth of it in the form of gypsum—in other words, 3,000 pounds of sulfur and 5,000 pounds of gypsum. These plots were then fallowed for 12 weeks, irrigating only often enough to keep the soil up to an optimum moisture content, and then were leached by keeping them completely submerged for three weeks. The result of these applications cannot be reported at this time as the plots are yet to be seeded, and samples for chemical analysis are not to be taken until later in the season.

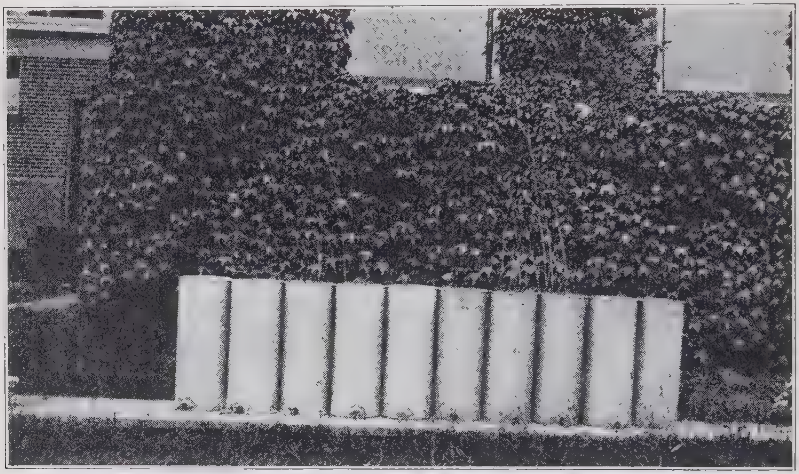

Fig. 10. Soil tanks for leaching experiments. Fourth from the left was treated with sulfur and manure. Nos. 7 and 8 were treated with gypsum.

As Kelley and Thomas[5] have pointed out, soil silicates in black alkali soils are apt to be saturated with sodium, as a result of the readily replaceable calcium having already been substituted in nature by sodium. For this reason, unless the soil is naturally high in calcium, the addition of this or a similar element may be necessary even if the acid formed by sulfur applications is effective in neutralizing all the carbonate, in order to improve the physical condition. When the calcium content is high, as is true of the soil under trial by the Oregon Station, it would seem that sulfur should be effective alone.

In order to study the effect of mixing various elements with sulfur a tank trial was started in the spring of 1924, and while this experiment has not run long enough to warrant any conclusions being drawn, a description of the experiment is thought worth while.

Twelve galvanized iron tanks 18 inches in diameter and 2½ feet in depth were equipped with drains for the purpose of collecting percolating water, and were filled with soil from the Vale experiment field, six being filled with soil that had been leached for three years, but had received no chemical treatment, and six with soil from an adjoining field which was still in grease wood, and which had received no treatment of any sort. These tanks were filled in the field, the soil being transferred in 4-inch layers so as to retain the same state as in nature, and packed so as to take up the same space as it did naturally. The tanks were placed in a trench with the top of the soil even with the surface of the ground, and were treated with (1) sulfur alone, (2) sulfur and gypsum, (3) sulfur and quicklime, and (4) sulfur and manure, the treatments being so applied that the same amount of sulfur was put on each tank. In the case of the sulfur and gypsum, one-fourth of the sulfur was put on in the form of gypsum, and in the case of the quicklime and sulfur mixture enough quicklime was put on to equal the amount of calcium in the sulfur and gypsum mixture. These tanks were left for 12 weeks at an optimum moisture content to allow the sulfur to oxidize and are now being leached. The rate of percolation and the chemical effect of the treatment on the soil and percolates are to be studied and also the effect of the treatment on crop yield.

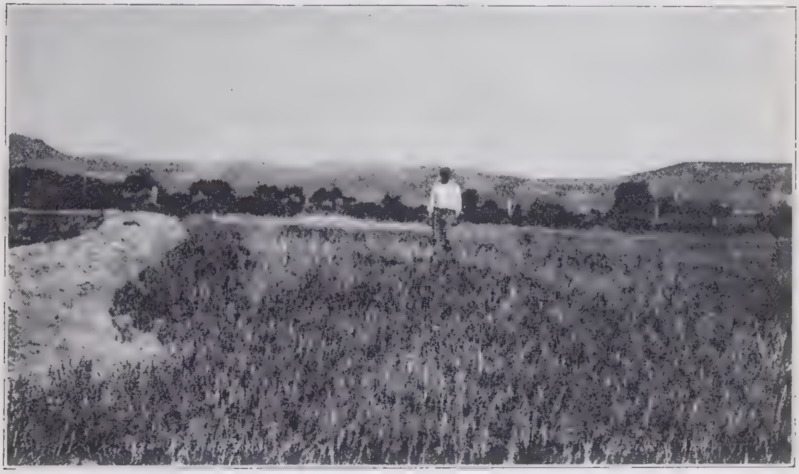

Fig. 11. Barley on partly reclaimed alkali land. Barley gives a short growth on alkali land. The heads usually fill well. On this field it was possible to secure a stand of sweet clover by irrigating and taking advantage of the shade and protection offered by the barley stubble.

### Effect of Aluminum Sulfate

Scofield and Headley[1, 3] have reported results from the use of aluminum sulfate on the impermeable black alkali soil as a treatment to improve the soil structure and correct the black alkaline condition. Aluminum sulfate has been used in the Vale experiment field in amounts from 500 pounds to 5 tons per acre. Little or no benefit resulted from the 500-1000 pounds or the 1 ton and 2 ton applications, but the application of 5 tons per acre resulted in a decided improvement. On one end of the check plot an area 30 feet square which received this application yielded a vigorous and thick stand of sweet clover, while no stand was secured on the remainder of the plot. The improvement in the physical condition and the rapidity of absorbing moisture were also very marked.

## Effect of Manure

Manure alone has not been effective in reducing the black alkaline content as determined by analysis or by the productivity of the land so treated, but it has resulted in an apparent improvement in the tilth and permeability of the soil to which it has been applied. As has already been mentioned the use of manure in combination with gypsum and with sulfur has been decidedly beneficial. Manure, upon decaying, produces carbon dioxide and it also aids the oxidation of sulfur. These conditions result in a temporary improvement in alkali soils, particularly in the surface two or three inches, and often make it possible to start crops on

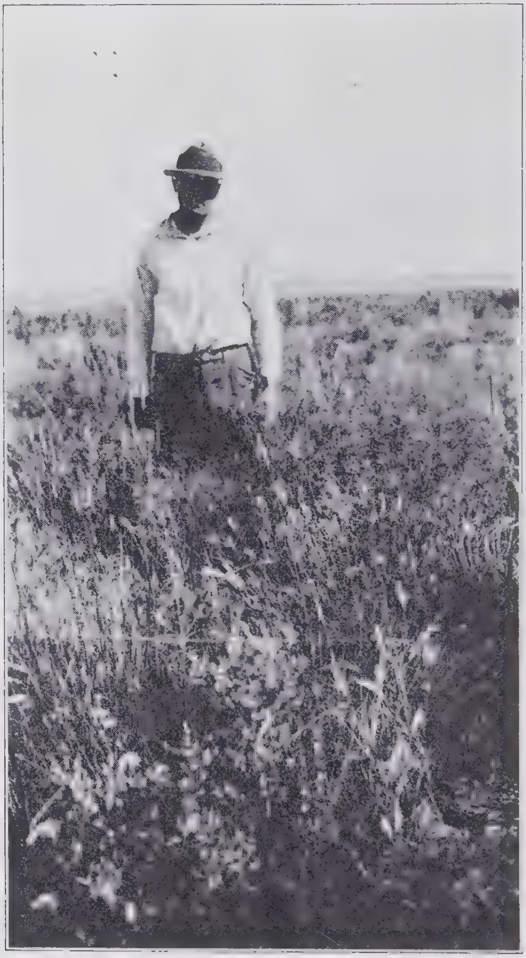

Fig. 12. Pasture on uncleared grease wood land. Native vegetation affords shelter, and a good stand of pasture grasses has been secured on drained and leached uncleared alkali land, where the same methods on cleared and cultivatd land have been unsuccessful.

land so treated even if the reclamation is not complete and permanent. Many of our crops will withstand considerable amounts of alkali if once established. This is particularly true with sweet clover and to a lesser extent with alfalfa. Treatments of this sort are therefore often profitable even where the application of enough chemical material to afford complete reclamation is not economically possible.

## Treatments and Crushing Loads Required to Crumble Sample

In order to get some check on the effect of treatments that were being used in the field on the soil structure, an amount of the surface soil was sent to the laboratory from the Vale experiment field, and the following experiment was conducted. A number of 453-gram samples were treated as shown in Table VI, the amounts being similar to those applied in the field, and were uniformly compacted on a shaker in one-pint cups. Samples were then moistened to saturation and were allowed to sun- and air-dry for a period of two months. By this time the samples had become dry and hard, and the crushing load required to crumble them was determined in the experimental engineering laboratory, the result being recorded in Table VI. It will be noted that the heavier gypsum treatment made the soil crumble more easily. The manure-and-sulfur treatment was also effective.

Field experiments bear out these results in that soils that have been treated with organic matter and also the gypsum plots worked up into good tilth much better than land that had not been so treated.

## Effect of Vegetation

When black alkali lands occur in small areas on farms or when such lands are included in districts that have to meet irrigation assessments, it is often important to be able to secure some returns from such lands, even if complete reclamation is not economically possible. It is also thought that the importance of the protection of the land from heat and excessive sunlight has not been given enough attention in attacking the black alkali problem and that the growth of some sort of vegetation on alkali land whether profitable or not, is desirable in that it will help to keep the soil from becoming badly affected.

Light, temperature and humidity may affect toxicity and assimilation,

TABLE VI. EFFECT OF TREATMENTS ON CRUSHING LOAD REQUIRED TO CAUSE BRICKS TO FAIL

| Sample | Treatment | Field rate per A. | Lab. Amt. for 1 pound soil | Irrigation | Crushing load |
|---|---|---|---|---|---|
| 1 | Manure | 20 T. | 9 gr. + .0543 | 175 c.c. each | 112.25 |
| 2 | Manure + sulfur | 20 T. M.<br>200 lbs. S. | 9 gr. + .1628 | 175 c.c. each | 125.00 |
| 3 | Manure + gypsum | 20 T. M.<br>600 Gyp. | 9 gr. + .453 | 175 c.c. each | 117.20 |
| 4 | Straw | 2 T. | .9000 | 175 c.c. each | 99.00 |
| 5 | Green manure | 4 T. | 1.8000 | 175 c.c. each | 158.00 |
| 6 | Sulfur | 200 | .0543 | 175 c.c. each | 152.50 |
| 7 | Sulfur | 400 | .1086 | 175 c.c. each | 122.00 |
| 8 | Check | | .0814 | 175 c.c. each | 139.50 |
| 9 | Gypsum | 300 | .1628 | 175 c.c. each | 150.70 |
| 10 | Gypsum | 600 | .2442 | 175 c.c. each | 74.00 |
| 11 | Gypsum | 900 | .0814 | 175 c.c. each | 64.10 |
| 12 | Aluminum sulfate | 600 | .1628 | 175 c.c. each | 124.00 |
| 13 | Aluminum sulfate | 600 | .2242 | 175 c.c. each | 117.40 |
| 14 | Aluminum sulfate | 900 | ------- | 175 c.c. each | 108.30 |

which are worse with high temperature, strong light, and low relative humidity.

The presence of any vegetation on the surface of the soil affords protection from upward leaching or excessive drying and makes it easier to get a stand of any new crop. It has been observed, moreover, and is well known by farmers who have had experience in farming land of this sort, that it is easier to get a stand and secure a crop from land that has not been plowed deeply, due apparently to the organic matter on or near the surface, and the effect of weathering on the physical condition of the surface soil. It is helpful to keep the surface salts diluted with frequent irrigation; also there is generally some protection afforded by grass and weeds.

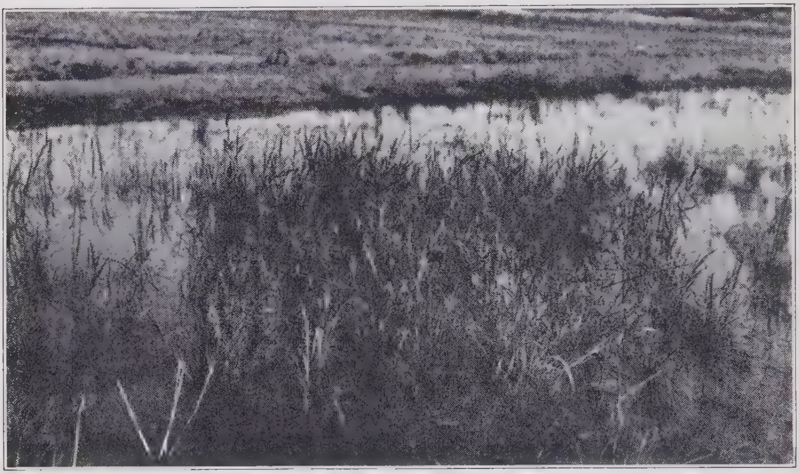

Fig. 13. *Echinochloa crusgalli* (L). Beauv., locally called "water grass."

## TAME PASTURE IN UNCLEARED GREASE WOOD LAND

In attempting to study this phase of the problem, an area of uncleared land supporting a growth of grease wood, mixed with a small amount of sage, and some salt grass, was diked in the spring of 1922 and flooded by allowing water to run on at the upper end, spread over the land, and run off the lower end. Flooding was continued during the summer of 1922 and in September this area was seeded to a mixture of bluegrass, redtop, timothy, meadow fescue, alsike clover, and sweet clover. Flooding was then continued for two weeks and was followed with frequent irrigations until the irrigation season closed. An adjoining plot was irrigated and seeded the same, but this had been cleared, plowed, and cultivated. On the uncleared area a good stand of grass and clover was secured, while on the cleared tract no germination was apparent and absolutely no stand was secured. The grass on the uncleared area was best in the shelter of the grease wood clumps, and lived through the winter only when protected by the grease wood and salt grass. During the next summer it continued to grow vigorously and spread out, covering the bare places. During the summer of 1924 this spreading continued so that there is now a fine stand of pasture mixture wherever the water ran over the land. Since this area was not leveled, there were some spots in the check where the water stood too deep for best results. On these areas some wild grasses, such as sedges, and some of the redtop were all that grew. In certain other spots, which were not flooded, no stand was secured. This land has afforded excellent pasture, the carrying capacity being at least half that secured on similar pastures in the vicinity grown on productive land.

This system provides a cheap method of securing some return from black alkali land, and it is believed that the protection provided by the pasture, combined with irrigation, will at least keep the land from becoming any worse and should provide partial reclamation due to the carbon dioxide formed as a result of rotting vegetable matter, shading, and downward leaching from frequent irrigations. This study is not completed. It is planned after the pasture has run for about four years to plow the area and treat it chemically. It is expected that a smaller amount of sulfur or gypsum will be required than on land that has not been given the pasture treatment. In the meantime, it will have brought some income, enough at least to take care of the taxes and annual cost of water, and will have effected partial reclamation.

## Handling Hard Alkali Land

All grease wood land is not flat enough to permit the use of this method without first leveling. After land is cleared and leveled, however, the surface should be disturbed as little as possible. Where the black alkali is not too bad it has been found profitable to secure a stand of sweet clover and pasture grasses by seeding in the early fall and giving the land frequent irrigations. Best results have been secured by disturbing the surface soil as little as possible and allowing the salt grass and native vegetation to grow to provide protection. Rye or millet seeded in the salt grass has given better results than when seeded on plowed and carefully cultivated land. The system of seeding grease wood land to pasture mixture and the frequent irrigation required for pasture are safe, of course, only when the soil is well drained naturally or artificial drainage is provided.

On land that has been partly reclaimed by the use of gypsum and that has been leached, the most successful method of securing a stand of sweet clover has been to work up the surface, 2 to 3 inches, into a fine seed bed by use of a disk harrow and clod-crusher. The seed is then broadcasted and planked in. Following this the land is corrugated and then kept moist by irrigating in the corrugations without flooding. Irrigation is continued in this way until the crop is up, without allowing the surface to become dry. This method keeps the remaining alkali diluted and prevents baking. It has been most effective with late summer seeding.

## Choice of Crops

During the four seasons that the Oregon experiments have been in progress about twenty types of pasture, grain, and root crops have been tested. On partly reclaimed black alkali land fall rye has proved the easiest to establish and has given fair yields of rye hay.

White sweet clover (*melilotus alba*) has been the most effective in improving the soil condition. This crop stands a great deal of alkali and produces well when once established, but is sensitive to alkali when young and difficulty has been experienced in getting a stand.

On uncleared pasture land blue-grass, meadow fescue, redtop, timothy, and alsike clover have been grown successfully. A native slough grass locally known as "water grass," *Echinochloa crusgalli* (L.) Beauv. (see Fig. 13), has been grown. This grass will germinate and grow in standing water, and a stand was secured by broadcasting before adding heavy irrigations for leaching purposes. The grass is considered by local farmers to have fair value for pasture and as hay for wintering stock.

Latest developments indicate an excellent stand of sweet clover where heavy applications of sulfur or gypsum were fallowed in during the past summer and seeded in early autumn. A combination of sulfur and gypsum gives indications of being more effective than either applied singly. The heaviest sulfur application has caused a little injury, but this will probably be only temporary, due to slight excess of acidity in the surface soil for the time being.

TABLE VII. ALKALI REMOVED IN PERCOLATES — SOIL TANKS — VALE SOIL
(Expressed as salts of sodium)

| | Plot | Irrigation | Percolation | $Na_2Co_3$ | $NaCl$ | $Na_2So_4$ | Tl. salts | PH Samples March '24 |
|---|---|---|---|---|---|---|---|---|
| | | *c.c.* | *c.c.* | *gr.* | *gr.* | *gr.* | *gr.* | |
| 1. | Check | 56,111 | 32,039 | 107 | 71 | 103 | 281 | 8.2 |
| 2. | Aluminum sulfate 2.5 T. | 57,525 | 30,331 | 151 | 85 | 154 | 390 | 8.2 |
| 3. | Aluminum sulfate 5 T. | 56,798 | 25,721 | 92 | 68 | 144 | 304 | 7.7 |
| 4. | Sulfur 1000 lbs. Manure 20 T. | 57,525 | 31,569 | 85 | 70 | 141 | 286 | 8.2 |
| 5. | Sulfur 1000 lbs. | 59,706 | 20,597 | 52 | 45 | 141 | 238 | 7.8 |
| 6. | Sulfur 500 lbs. | 53,344 | 15,722 | 68 | 65 | 64 | 197 | 8.1 |
| 7. | Gypsum 10 T. | 57,525 | 31,709 | 109 | 68 | 224 | 401 | 7.8 |
| 8. | Gypsum 5 T. | 57,525 | 28,060 | 76 | 42 | 151 | 269 | 7.9 |
| 9. | Manure 20 T. | 57,525 | 30,454 | 145 | 87 | 112 | 324 | 8.7 |
| 10. | Check | 57,525 | 31,409 | 123 | 82 | 115 | 320 | 8.8 |

## TANK EXPERIMENTS

In the fall of 1922 ten soil tanks, 2 feet in depth and 11 inches in diameter, were filled with alkaline soil shipped from the experiment field at Vale, and were placed in the greenhouse at Corvallis, for the purpose of checking the field work and studying the effects of various treatments, on the amount and composition of the percolates resulting from heavy irrigations.

### Effect of Various Treatments on Salts Removed in Percolates

### (Table VII)

The tanks were given treatments corresponding to the main applications used in field trials; the irrigation waters and percolates have been measured, and the latter analyzed. The results from the time the experiment was started through 1923 are summarized in Table VII.

In column 1 will be found the treatment given each tank, recorded on the acre basis. Column 2 records the total irrigation applied, and column 3 the total percolate, both expressed in cubic centimeters. In the next four columns are recorded the salts removed, expressed in each case as grams of the material contained in the total percolate. These results were secured by determining the $CO_3$, Cl, $SO_4^{=}$ and total salts. For purposes of comparison these have been calculated and are reported as salts of sodium.

The amount of sodium carbonate removed does not give a true conception of the value of the various chemical treatments, for their effect is to neutralize the carbonate. Gypsum, for instance, unites to form sodium sulfate and calcium carbonate, and since the latter is not readily soluble, the larger amount of sulfate indicates that considerable of the sodium carbonate had been neutralized, the sodium passing on as sodium sulfate and the $CO_3$ remaining in the form of calcium carbonate. The rate of percolation was slower for check tanks, yet the total amount of percolate from these is comparable with treated tanks since treatments increased water capacity of the latter.

## Effect of Treatments on Crop Production

In March, 1923, after having been leached intermittently for six months, the tanks were seeded to rye and sweet clover. The results are recorded in Table VIII.

It will be noted that rye produced best on the gypsum tanks, the tanks receiving the 5-ton aluminum sulfate treatment being second, and the sulfur and manure tank third. The best stand of sweet clover was secured on the same tanks.

In the fall of 1923 the tanks were subjected to further leaching and then seeded to vetch. No stand was secured on any tanks except the two receiving a gypsum treatment. On tank 8, which had received gypsum at the rate of five tons per acre, the vetch grew to be about two inches high and then grew no further. On tank 7, which had been treated with ten tons of gypsum, the vetch grew very luxuriantly and was fourteen inches high when turned under on February 19.

TABLE VIII. EFFECT OF TREATMENTS ON YIELD OF RYE, AUGUST 3, 1923. ALKALI TANKS

All had 10 rye and 18 sweet clover plants started or set in.

| | Treatment | No. rye plants at harvest | Average height | Number of heads | No. plants sweet clover August 3 | Average height | Net green weight rye | Net oven dry weight rye | Total irrigation 4/2 8/3 '23 |
|---|---|---|---|---|---|---|---|---|---|
| | | | in. | | | in. | gm. | gm. | in. |
| 1. | X | None | | | 0 (1 salt grass) | 0 | -------- | 0. | 8½ |
| 2. | Aluminum sulfate 2.5 T. | 10 | 24 | 3 | 5 | 5 | 9.90 | 5.12 | 8½ |
| 3. | Aluminum sulfate 5 T. | 10 | 27 | 6 | 5 | 5 | 22.15 | 11.80 | 8½ |
| 4. | S. 1000 M. 20 T. | 9 | 27 | 3 | 5 | 5½ | 19.95 | 10.42 | 8½ |
| 5. | S. 1000 lbs. | 6 | 8 | 1 | 1 (grease wood) | 0 | 1.35 | .95 | 8½ |
| 6. | S. 500 | 6 | 6 | 0 | 4 | 9 | 2.95 | 1.35 | 8½ |
| 7. | Gyp. 10 T. | 10 | 30 | 7 | 8 | 4 | 37.95 | 19.05 | 8½ |
| 8. | Gyp. 5 T. | 10 | 33 | 7 | 5 | 4⅓ | 32.80 | 17.90 | 8½ |
| 9. | M. 20 T. | 9 | 7 | 0 | 2 | 9 | 6.35 | 3.30 | 8½ |
| 10. | X (Had more shade and moisture) | 6 | 7 | 1 | 3<br>Reseeded 8/3 | 6 | 6.60 | 3.28 | 8½ |

The tank experiments have checked the field work and show the effectiveness of heavy gypsum and aluminum sulfate treatments and of sulfur and manure. They also add evidence of the usefulness of small chemical treatments on this type of soil. The chemical effect of heavier sulfur treatments applied to three of these tanks in January, 1924, is included under the discussion of sulfur.

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Station Bulletin 211 February, 1925

Oregon Agricultural College

Experiment Station

# A Study of the Biological Activities in Certain Acid Soils

By

WILLIAM V. HALVERSEN

1885

CORVALLIS, OREGON

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## SUMMARY

The results of this investigation concerning the relation of lime to the production of plant food in certain prominent soil series of the Willamette Valley can be summarized as follows:

1. The micro-flora of these soils under greenhouse conditions shows a response to the application of lime that is in keeping with the reports of investigators in other sections of the country.

(a) The ammonifying power is little affected by liming, which would indicate that crops capable of utilizing ammonia as a source of nitrogen need not starve.

(b) The nitrifying power of these soils is greatly stimulated by the application of lime. This would lead one to believe that plants requiring nitrates will not give maximum yields and will suffer from lack of nitrogen unless at least part of the lime requirement is satisfied.

2. The sample of Soil III (Amity silt loam) showing response to lime under field conditions gives a corresponding response to biological tests. A similar biological response is noted in samples I (Willamette silty clay loam) and II (Dayton silty clay loam). These soils are not always believed to give crop response.

3. Under greenhouse conditions an increase in the yield of clover was obtained on Soils I and II. The failure of Soil III to show a similar response is probably due to the fact that this soil had previously been limed in the field where it showed great crop response. It undoubtedly contained particles of limestone.

4. Samples of soil taken from fallow plots of Willamette silty clay loam that had been limed at the respective rates of 0, 2, 4, and 6 tons of lime per acre gave consistently higher yields of nitrate than where no lime had been applied. Despite the fact that this soil had a pH value of 5.4 and a lime requirement of five thousand pounds per acre according to the Veitch method, the plot on which 6 tons of lime per acre had been applied contained larger quantities of nitrates than the plots where 0, 2, or 4, tons of lime were applied. The same relation pertained in regard to its nitrifying power.

5. Since the soil remains cold and wet until about the middle of May and this condition is quickly followed by a dry cool summer, there is normally such a short period of optimum moisture and temperature conditions for bacterial action in the soil that moisture plays a big part as a limiting climatic factor.

6. It is only logical to believe from the evidence given that these soils, under field conditions, will respond to the application of lime if a sufficient amount is added in a finely divided state unless other limiting factors such as lack of available phosphorus, or unfavorable climatic conditions, obscure any such response.

7. These investigations indicate that lime has a stimulating effect on those forces that operate in the production of plant food in the soils studied, yet it is beyond the scope of this investigation to determine the most economical method or even to determine whether the increases in yield due to liming will pay for the lime applied. This status must be determined entirely from field trials with the plants grown normally on these types of soil.

# A Study of the Biological Activities in Certain Acid Soils

By

WILLIAM V. HALVERSEN

## INTRODUCTION

The value of lime as a fertilizer has been demonstrated by extensive investigations carried out by numerous experiment stations. Voluminous is the literature showing field results from the application of lime to various crops under widely differing soil conditions. Crop response has been so varied under divergent soil conditions that no hard and fast rules can be formulated from the data accumulated. No attempt will be made to review the literature pertaining to this subject, reference being made only to outstanding investigations having a direct bearing on our problem.

There are several reasons for the diverse results obtained, chief among them being the feeding habits of the plants and the reaction and composition of the soil. Some plants can utilize ammonia as their principal source of nitrogen. These plants could thrive on soils containing no solid carbonate of lime.

## AMMONIA VS. NITRATE AS SOURCE OF NITROGEN

Kelly[22] shows that rice, grown in swamp land, secures its nitrogen in the form of ammonia. Hutchinson and Miller[24] show that peas are able to use ammonia nitrogen as well as nitrate nitrogen. Hall and Miller[21] call attention to the fact that ammonium sulfate, on the Park plots of the Rothamsted Farm, produces very good crops of grass, although the soil is deficient in lime and very little nitrification takes place. Bear[2] concludes that plants which depend on nitrates as their source of nitrogen may suffer from the lack of available nitrogen in soils having high lime requirements, unless these requirements have been at least partly satisfied.

## SOME PLANTS FLOURISH ON ACID SOILS

Certain plants of economic importance are injured by the application of lime while yet others are benefited. Wheeler[25] claims that Kentucky blue grass and timothy have less tolerance of soil acidity than orchard grass and meadow fescue, and that awnless brome grass, redtop and R. I. Bent grow well on decidedly acid soils. Coville[5] points out the fact that certain crops are injured by the application of lime. A cropping system has been suggested in which all the crops are acid tolerant, thus eliminating frequent and heavy applications of lime. Some crops adapted to acid soils are blueberry, cranberry, strawberry, blackberry, raspberry, potato, sweet potato, rye, oats, millet, buckwheat, redtop, corn, carrot, turnip, and legumes such as cowpea, soy-bean, hairy vetch, lupine, serradella, and crimson clover. In conclusion Coville states that "soil acidity is not always an objectionable condition which invariably requires an application of lime; that under certain economic conditions a complete system of acid-land agriculture is practicable and desirable."

## CERTAIN CROPS THRIVE ONLY ON ALKALINE SOILS

Some crops generally respond to the application of lime. Hartwell and Damon [22] show that on an extremely acid soil, Kentucky blue-grass, orchard grass, sheeps fescue, tall fescue, and timothy can not grow and are replaced by other grasses. Coville[8] points out the fact that the general advocation of lime to neutralize soil acidity is to make these soils produce larger crops of such staples as clover, timothy, wheat, and alfalfa. Hopkins[23] reports beneficial results from the use of lime on alfalfa. Fred and Graul[15] found lime to give an increase in the growth of clover and alfalfa; the increase was accompanied by an increase in the fixation of atmospheric nitrogen. They conclude that small applications of calcium carbonate on acid soils are far more economical.

## THE NUMBERS AND FUNCTIONS OF SOIL MICROORGANISMS

White[36] failed to confirm Hall's statement that nitrification ceases on very acid soils. It will be readily recognized that the base must be present to form the salt. There is the possibility that in the Pennsylvania plots under consideration, small particles of limestone may be present around which nitrification is in progress while the soil shows a decided acid reaction.

More recently Fraps[11] has found that some acid soils show high nitrifying power while others show a low nitrifying power. Noyes and Conner,[27] studying the nitrifying power of five typical acid soils, conclude that "the amount of nitrates present and the nitrifying power of the untreated acid soils varied with the organic matter and total nitrogen rather than with the soil acidity." Plummer[28] shows that when the supply of oxygen is limited and anaerobic conditions are produced, denitrification sets in, which continues until practically all the nitrates are destroyed. From the evidence available it seems apparent that nitrates are entirely of biological origin and that they are formed by the nitrite and nitrate bacteria. It has not been established whether or not the organisms responsible for nitrification in acid soils are the same as those in alkaline or neutral soils.

The non-symbiotic fixation of atmospheric nitrogen is influenced by the application of lime. Ashby[1] found the nitrogen-fixing power of Rothamsted soils to be more than doubled by the use of lime. Christensen and Larsen[7] found that the brownish scum which characterizes Azotobacter failed to develop on Ashby's solution when inoculated with an acid soil. Fred and Davenport[14] show the extreme sensitiveness of Azotobacter to slight changes in reaction. In mannitol solutions the limits were found to be pH 6.5 to 8.6. Gainey and Batchelor[16] found that the maximum acidity permitting appreciable growth of Azotobacter was close to pH 5.9. Given, Kuhlman, and Kern[18] in a study of non-symbiotic nitrogen-fixation in well drained clay loam or silty clay loam soils of the general fertilizer series at the Station found that the relative positions of the plots studied with reference to nitrogen fixation were remarkably similar to their relative positions in crop producing power in the cases of hay, oats, and wheat. They believe that the correlations observed were too numerous to be mere coincidence.

The number of bacteria in the soil varies with the treatment. Frear[12] found that lime increased the number of bacteria in field soils and that a complete fertilizer with ammonium sulfate materially decreased the number of bacteria present. This decrease he attributes in a large degree to the acid conditions of the soil. Fabricius and von Feilitzen[10] show the influence of lime on soil bacteria. They found 138,500 bacteria per gram in newly broken and unlimed peat soils; whereas in similar soils that had been limed and cultivated for several years the number averaged about 7,000,000 per gram, reaching a maximum of 22,132,000 per gram of soil. Ammonification is a function common to soil bacteria. Both molds and bacteria have been proved to function. This probably accounts for the fact that it is possible to have an acid soil with a high ammonifying power, thus permitting the system of acid-soil agriculture described by Coville. Taking into consideration the constant bacterial factor, ammonia production is greatly influenced by the chemical composition of the soil. Additions of lime and green manure would be expected to accelerate the activities of the B. subtilis group. Greaves and Carter,[19] studying the biological activities in a calcareous soil, found an increase in the ammonifying power on the application of manure up to 25 tons per acre. "The greatest increase per ton of manure was obtained in soil receiving 5 tons." Brown[5] shows a relation to exist between the ammonifying power of a soil and the yield of corn on variously treated soils. Beckwith, Vass, and Robinson[4] found a direct correlation between the amounts of ammonia formed and the number of bacteria; they found also that the number of bacteria present in soils low in organic matter is small compared with the number in the peat and muck soils. Lime had no effect upon the number of bacteria except in these soils showing acid conditions, or when large amounts of organic matter were added.

When large quantities of organic matter decay in the soil organic acids are formed. These organic acids react with the carbonate forming calcium salts. These organic salts can be readily attacked by molds and bacteria. The excess acid is leached out or neutralized by ammonia formed and thus we have a return to the alkaline reaction. Many bacteria are active in bringing about the formation of carbonates from the calcium salts formed by reaction with the organic acids. Hall and Miller[21] claim that the organic acids are broken up into carbon dioxide and water. The precipitation of calcium carbonate from solution by marine bacteria is demonstrated by Drew.[9] Bear and Salter[3] suggest that the lower lime requirement (Veitch) of plots high in organic matter may be due to the precipitation of calcium from the humus in the soil, thus preventing its being lost by leaching. It is probable that this return of bases through the mineralization of organic matter serves as a base to neutralize the acids formed during nitrification. This would account for the nitrate accumulating in acid soils.

## OBJECT OF THESE INVESTIGATIONS

These investigations seek to study prominent soil types of the Willamette Valley from the bacteriological standpoint with the object of determining the relation of lime to the production of plant food in these soils.

There is a difference of opinion among investigators and farmers in interpreting the yields of crops grown on these acid soils after lime has been applied. The terms "acid soil" and "lime requirement" have been taken generally to be quite analagous. Here is a specific case where there seems to be a difference. If any soil has a marked acid reaction it would only be logical to expect certain crops to respond when the acidity was neutralized. If acid-tolerant plants were grown, however, there would be no lime requirement. The questions that first come to mind are: Are we expecting results on acid-tolerant plants or do other limiting factors obscure possible crop response? Lime has proved its value as a fertilizer in many states; is our particular condition an exception? Fred and Graul,[15] found that clover and alfalfa growing on Colby silt loam and Plainfield sand were able to fix considerable amounts of nitrogen having only one-half of their acidity (Truog) neutralized; how would this check on our local soils?

The following experiment was outlined with the view to eliminating the many climatic and physical factors encountered in field work and to establish any possible relation between the "acidity" and "lime requirement" of the soils and crop response. It must be remembered that acid soils are commonly deficient in total phosphorus. In such a case both phosphorus and lime would be limiting factors, each obscuring any response that would normally occur. The fineness of grinding of the limestone is a determining factor as to the promptness and extent of the crop response.

Brown[6] found a correlation between certain bacterial activities in soils and their crop-producing power under field conditions. Under these conditions he found that liming increased the ammonifying power, and the yield of corn. Voorhees, Lipman, and Brown[33] found that the application of lime reduced the yields of dry matter in many instances, but increased the yields of nitrogen. Both ammonification and nitrification, however, were accelerated by the addition of lime. Sievers[31] says, "Soil-fertility studies in Western Washington indicate conclusively that most acid soils are deficient in phosphorus, and that application of lime alone generally gives poor results unless it is supplemented with a phosphate fertilizer. Indications are that much of the difficulty experienced in growing clover is due more to the deficiency in phosphorus than to soil acidity." Since the climatic conditions in Western Washington are very similar to our local conditions these results might well be taken as an indication of what to expect here. With these previous results in mind an experiment was outlined to correlate the crop-producing power of a soil and its bacterial activities under controlled conditions in the greenhouse, thus eliminating any possible limiting climatic and physical factors.

## "REACTION" AND "LIME REQUIREMENT"

Many interpretations have been placed on the meaning and causes of soil acidity. It is not within the limits of the present discussion to attack this phase of the subject. One fundamental point in general agreement, however, is that whether soil acidity is due to active aluminum, acid silicates, or what not, lime has been used with good effect in overcoming the toxic principle.

## SOILS USED IN THIS EXPERIMENT

In this investigation three samples of soil were used, each representing a soil series prominent throughout the Willamette Valley. The descriptions are based on Soil Survey reports covering these soils.

Soil I was secured from the uncropped border between two plots on the Oregon Agricultural Experiment Station. It is classified as Willamette silty clay loam. In the Soil Survey Report[26] it is described as follows: "The surface soil consists of 12 to 18 inches of mellow brown silt loam with an average depth of about 15 inches. In certain stages of moisture content the color of the surface is a dull chocolate brown. The subsoil is a brown silt loam to light clay loam, which either continues to a depth of 3 feet or more without material change or passes at depths varying from 24 to 30 inches into friable brownish-yellow silt loam containing a relatively large proportion of very fine sand.

"This is an important soil type both in regard to area and in point of use. Probably 85 percent of it is under cultivation, and the rest, which is mostly confined to the vicinity of streams, supports valuable forests of fir. The principal crops are wheat, oats, red clover, alsike clover, and oat-and-vetch hay. The clovers are grown both for hay and for seed. Wheat and clover seed are the chief cash crops, the former occupying nearly one-third of the area of the type. Aside from the crops enumerated, corn is grown both for silage and for grain, and potatoes, berries, vegetables, and fruits are produced on nearly every farm."

The sample taken had a lime requirement of 5,000 lbs. per acre by the Veitch method, and a pH value of 5.4.

Soil II was taken from the uncropped border between two plots located in the area just south and west of the Men's Dormitory on the Oregon Agricultural Experiment Station. The soil is classified as "Dayton silty clay loam" and is known locally as "white-land" due to its whitish appearance when dry. It is described in the Soil Survey Report[26], as "consisting in the virgin condition of 2 to 4 or 5 inches of light-brown to grayish-brown silt loam, the depth to which the horizon extends depending on the surface drainage."

This is underlain by a gray to white silt loam ranging in thickness from a few inches to more than one foot. It may vary from a uniform gray or white to white with brown spots. When wet the soil is rather plastic, and on drying becomes hard and intractable. It is low in content of organic matter, and the surface of freshly plowed fields has a characteristic white appearance.

The topography is nearly level, many of the fields being so flat that the water stands on the surface for weeks at a time. The entire type has inadequate surface drainage, and the impervious layer in the subsoil prevents the downward passage of water, with the result that the soil becomes saturated soon after the fall rains begin and remains in this condition until late in the spring.

This sample gave a lime requirement of 1430 pounds per acre by the Veitch method, and a pH value of 5.4.

Soil III was taken from the farm of C. C. Dickson near Shedd, Oregon. It has been classified as Amity silt loam and was chosen because of the crop response noted on the application of lime. It is described in the Soil Survey Report[26] as follows:

"The Amity silt loam is an intermediate type between the Willamette and the Dayton silt loams. The surface soil consists of 10 to 15 inches of light brown to light grayish brown silt loam, of an average depth of 12 inches. The subsoil in most places is composed of two sections. The upper section, extending to a depth of 24 to 30 inches, consists of a mottled light-brown to light grayish brown silt loam or silty clay loam of moderately compact structure. The lower section is composed of light-brown silt loam or silty clay loam mottled with gray, rusty brown, or brownish yellow, and as a rule somewhat lighter in texture and a little more friable in structure than the upper subsoil.

"The Amity silt loam is one of the most extensive soil types in the Yamhill and Willamette valleys. It occurs in all parts of the valleys in irregularly shaped areas intimately associated with the Willamette and Dayton silt loams."

This sample gave a lime requirement of 2140 pounds per acre by the Veitch method and a pH value of 6.6.

## GENERAL PLAN OF THE EXPERIMENT

The samples of soil for this experiment were taken in the spring when the moisture was slightly below optimum. They were passed through a 10-mesh sieve and placed in 4-gallon crocks. Eight jars were filled with each soil and duplicate jars treated as follows: no lime, two tons, four tons, and six tons of pure calcium carbonate per acre. The moisture was raised to 30 percent (air dry basis) and the jars were placed in the greenhouse to incubate.

Duplicate jars having been prepared previously, one of each set was planted to wheat. The plants were later thinned to 20 per jar. The other set of jars were covered to prevent evaporation and samples were taken at regular intervals for laboratory tests. The two sets of jars made it possible to work out a correlation between these samples of soil as to their crop-producing power, biological activities, and response to the application of lime.

During the summer, mildew proved to be such a hindrance to the growth of the wheat seedlings that it was necessary to remove them and seed the jars to red clover. Clover is not an ideal crop for this kind of work because of the difference in the amount of nitrogen fixed by the plants growing in the different reactions. These plants were thinned to 12 per jar. They were inoculated by washing the organisms off a large agar slant into the water used to irrigate the plants. This eliminated the possibility of any material difference in the inoculation of the plants.

The fallow pots were sampled at regular intervals and the ammonifying, nitrifying, and non-symbiotic nitrogen-fixing powers determined. The numbers of bacteria and molds were enumerated usually at the same sampling. The incubation work was started on June 25, 1920. The first samples were taken August 13, thus giving the soil microorganisms time to adjust themselves to the changes in soil reaction.

At the time of sampling the samples were taken to the laboratory and passed through a 10-mesh sieve. The sieve was sterilized before using on each different sample. One-hundred-gram portions of these soils were weighed into jelly glasses. Dried blood was used in the ammonification tests, ammonium sulfate was used in the nitrification tests, and dextrose was used for the non-symbiotic nitrogen-fixation tests. These were mixed into the soil by spreading the soil upon a piece of oilcloth that had previously been washed with alcohol and manipulating the soil back and forth until they were thoroughly mixed. After placing the treated soil back in the tumblers, enough moisture was added to bring the percentage up to 30 percent air-dry basis. The tumblers were incubated at room temperature.

Methods of analysis: The ammonia and total nitrogen distillations were made by aeration according to the procedure outlined by Potter and Snyder.[29] The total nitrogen digestions were made using Hibbard's method which has been shown by Snyder[32] to be quite as satisfactory as the methods modified to include nitrates. The nitrates were determined by the phenoldisulfonic acid method as outlined by Fred,[13] the comparisons being made with a Kober colorimeter.

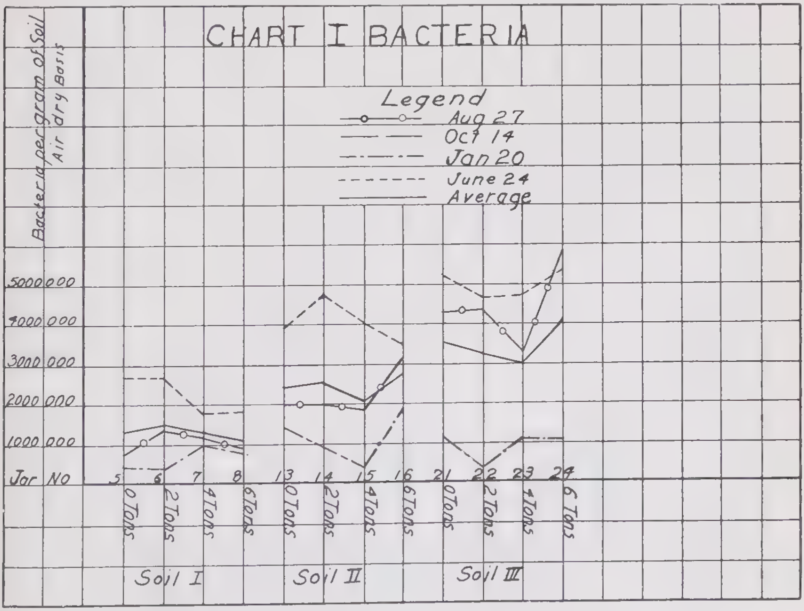
## THE EFFECT OF LIMING ON THE NUMBER OF BACTERIA

Lipman's modified synthetic agar was used for all plating. The reaction of the medium was adjusted to pH 7.4. The results are presented in Table I and are shown graphically in Chart I.

Soil I was placed in jars numbered five, six, seven, and eight, which represent the application of no lime, two, four, and six tons of lime per acre respectively. Wide variations in the number of bacteria occur, and the ratio of one sampling to another varies widely. It does appear, however, that liming has little effect on the number of bacteria present.

Soil II is represented by numbers 13, 14, 15, and 16. Here despite the uniform depression in the count of jar 15, which represents four tons of lime per acre, there is a marked increase in number present with the application of 6 tons of lime when compared with the check, and with 2 tons per acre.

Soil III presents a peculiar problem. Two tons of lime per acre caused a depression in the number of bacteria; this depression was increased by the application of 4 tons per acre, while on the application of 6 tons of lime, a stimulation brought the total count above that of the



check. This would indicate that the growth of some particular group of organisms had been stimulated. A very striking correlation existed between the bacterial count and the yield of clover on this type of soil.

TABLE I. BACTERIA PER GRAM OF SOIL X 1000

| Date | Jar | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 13 | 14 | 15 | 16 | 21 | 22 | 23 | 24 |
| Aug. 27 | 800 | 1360 | 1250 | 950 | 2030 | 2030 | 1900 | 3200 | 4300 | 4350 | 3330 | 5850 |
| Jan. 20 | 450 | 433 | 1000 | 766 | 1400 | 866 | 400 | 1850 | 1133 | 500 | 1050 | 1100 |
| June 24 | 2700 | 2730 | 1800 | 1830 | 3960 | 4860 | 4060 | 3530 | 5260 | 4760 | 4800 | 5360 |
| Average | 1317 | 1508 | 1350 | 1182 | 2463 | 2552 | 2120 | 2860 | 3564 | 3203 | 3060 | 4103 |

In general these results indicate that the total number of bacteria present is generally stimulated in soils II and III by the application of lime. In no case is there a really consistent correlation, however, between the lime applied and the number of bacteria. After making a careful study of the effect of fertilization upon the numbers of microorganisms in the soil, Waksman[34] says, "It would, therefore, seem conclusive . . . that the total number of microorganisms as determined by the plate method can serve as a function of the bacteriological condition of the soil and as an index of soil fertility. The relative numbers of bacteria, actinomycetes and fungi indicate also the chemical condition of the soil." He found that the addition of lime resulted in a decrease in the numbers of fungi and an increase in the numbers of bacteria and actinomycetes. It is not possible to make such definite statements from the results presented here. It is possible, however, that difference in technique and conditions of the experiment may account for this lack of concurrence.

## THE EFFECT OF LIMING ON THE NUMBER OF MOLDS IN THE SOIL

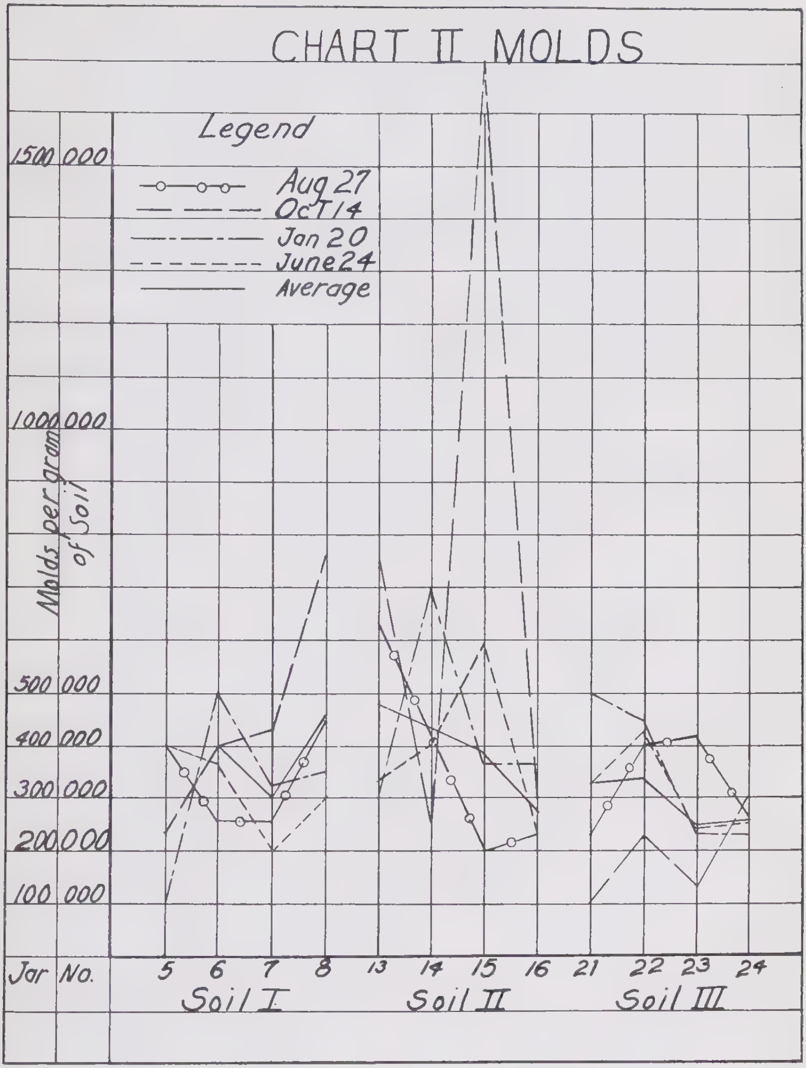
The term "mold" is applied to those forms showing distinct hypha after one week's incubation at room temperature. The number of molds fluctuates widely. It is very hard to procure consistent results. This is probably due to the presence of spores and to the fact that the medium used was not particularly adapted to the growth of molds.

TABLE II. MOLDS PER GRAM OF SOIL X 1000

| Date | Jar | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 13 | 14 | 15 | 16 | 21 | 22 | 23 | 24 |
| Aug. 27 | 400 | 260 | 260 | 460 | 530 | 360 | 200 | 230 | 230 | 400 | 410 | 270 |
| Oct. 14 | 233 | 400 | 430 | 760 | 760 | 260 | 1700 | 300 | 100 | 230 | 130 | 300 |
| Jan. 20 | 125 | 550 | 330 | 350 | 300 | 700 | 370 | 370 | 500 | 450 | 230 | 230 |
| June 24 | 400 | 370 | 200 | 300 | 330 | 400 | 600 | 230 | 470 | 270 | 170 | 230 |
| Average | 239 | 395 | 305 | 468 | 480 | 430 | 390 | 283 | 325 | 338 | 235 | 258 |

Despite the erratic counts obtained in several cases, Soil I shows a marked though inconsistent increase in the number of molds. This is the only soil having a marked acidity and the only one showing an increase in the number of molds present with the application of lime. It would appear that the application of lime to this soil stimulated the activities of certain fungi.

In both Soil II and III a decrease in the number of molds with the application of lime is quite apparent. The very abnormal count obtained with four tons of lime on October 27 was not included in the average. The foregoing data seem to indicate that where lime stimulates the number of bacteria in the soil, a definite depression in the number of molds occurs simultaneously. Studies on the nitrifying power of these soils show an interesting contrast between the graphs depicting the number of molds present and the nitrifying power of the soil.



## THE INFLUENCE OF LIME ON THE PHYSIOLOGICAL ACTIVITIES

### Ammonification

Since the power of transforming protein and its cleavage products into ammonia is a function of most soil bacteria and fungi and since certain of the more widely prevalent molds are capable of growing in the presence of relatively large quantities of free acids, lime would not be expected to affect so grossly the ammonifying power as it would change the species relationships. The author has grown Aspergillis niger successfully in sugar broth of pH 1.8. Considering the comparatively narrow range of acidity in farm lands one might expect to find a vigorous ammonifying power though the soil is decidedly sour. The greatest results would probably be noted in the species relationships rather than through the amount of transformation accomplished.

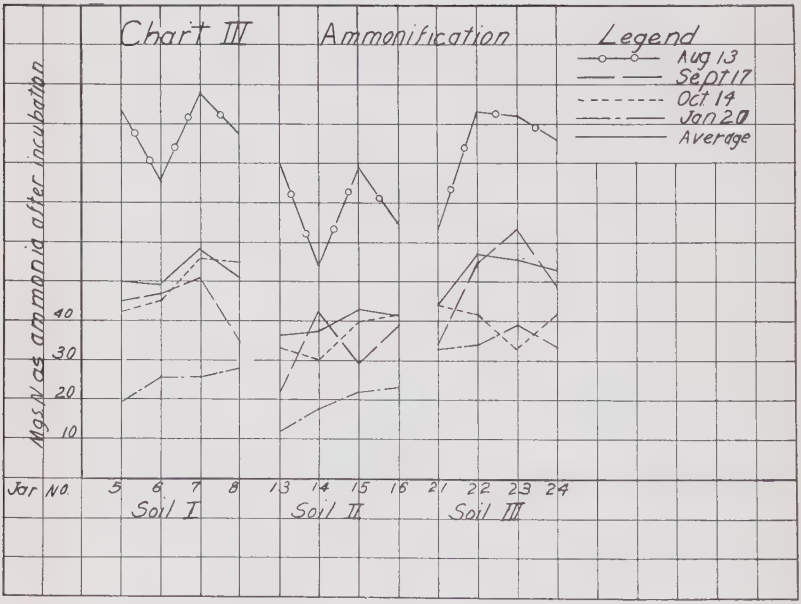


TABLE III. AMMONIFICATION

Mgs. N as $NH_3$

| Date | Jar 5 | 6 | 7 | 8 | 13 | 14 | 15 | 16 | 21 | 22 | 32 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug. 13* | 93.2 | 76.3 | 98.4 | 87.8 | 80.5 | 63.7 | 79.5 | 64.8 | 63.1 | 97.8 | 92.4 | 86.0 |
| Sept. 17 | 45.3 | 47.5 | 51.2 | 35.0 | 21.9 | 42.4 | 29.5 | 39.1 | 34.5 | 55.4 | 63.3 | 49.7 |
| Oct. 14 | 42.1 | 45.9 | 56.9 | 55.5 | 32.8 | 30.0 | 40.2 | 42.2 | 44.8 | 41.5 | 33.5 | 42.8 |
| Jan. 20 | 18.6 | 26.1 | 25.7 | 27.2 | 11.7 | 18.2 | 21.5 | 23.1 | 33.5 | 33.7 | 39.3 | 32.6 |
| June 24 | 22.3 | 24.3 | 18.7 | 22.3 | 21.4 | 19.6 | 25.9 | 20.8 | 24.7 | 24.0 | 20.0 | 24.3 |
| Average | 32.1 | 35.9 | 38.1 | 36.7 | 21.9 | 27.7 | 29.3 | 31.3 | 34.4 | 38.6 | 39.0 | 37.3 |

* Not included in average.

The very high yields of ammonia obtained on August 13 are probably due to the rise in room temperature during the hot part of the summer. Disregarding the inconsistent results obtained on this sampling, Soil I gave a marked increase in its ammonifying power on the addition of both 2 and 4 tons of lime respectively. Six tons of lime per acre also showed marked results; the yield of ammonia, however, is less than with the smaller applications of lime. Since the lime requirement of this soil is two and one-half tons (Veitch) per acre, it would seem that the maximum proteolytic activity (as measured by the $NH_3$ produced) was not reached until after the total acidity was neutralized.

Soil II gives on the average a greater increase in ammonifying power up to and including the application of 6 tons of lime per acre. This soil is low in organic matter and has a poor structure; the increase therefore may be due largely to the improvement in structure and its effect on the aeration of the soil.

Soil III seems to reach its maximum ammonifying power on the application of 4 tons of lime per acre. Use of 6 tons of lime gave an increase in the ammonifying power of Soil III, yet the yield of ammonia was less than where the smaller applications of lime were made.

In general it may be stated that on Soils I and III an application of lime at the rate of 6 tons per acre caused a marked decrease in the ammonifying power of these soils when compared with the application of two and four tons respectively. Compared with the smaller applications, application of lime far beyond the amount necessary to neutralize the acidity appears to have a depressing effect on ammonification.

## Nitrification

The results are very apparent. The rate of nitrification is correlated with the amount of calcium carbonate supplied. In no case is there any apparent retarding effect on the nitrifying organisms. This confirms the results of Bear.[2]

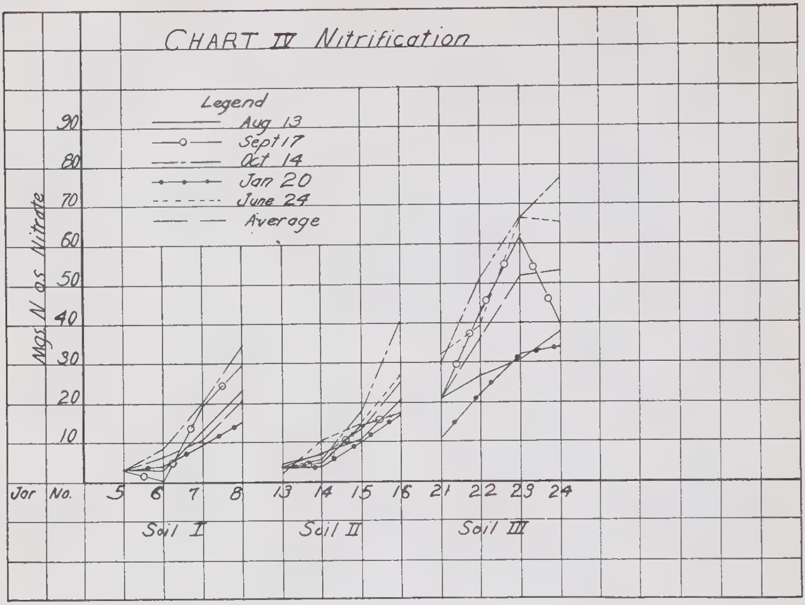
TABLE IV. NITRIFICATION

Mgs. N as $NO_3$ per 100 grams soil

| Date | Jar | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 13 | 14 | 15 | 16 | 21 | 22 | 23 | 24 |
| Aug. 13 | 2.4 | 3.4 | 12.6 | 23.2 | 3.3 | 7.1 | 10.8 | 21.7 | 21.7 | 27.0 | 31.9 | 38.5 |
| Sept. 17 | 2.9 | *0.6 | 19.0 | 29.9 | 3.8 | 5.3 | 14.3 | 18.8 | 21.7 | 41.7 | 62.5 | *40.0 |
| Oct. 14 | 2.2 | 8.6 | 19.8 | 43.5 | 4.0 | 6.2 | 18.1 | 40.0 | 20.3 | 50.8 | 66.6 | 76.9 |
| Jan. 20 | 2.2 | 3.7 | 9.0 | 14.7 | 2.5 | 4.3 | 10.1 | 17.6 | 11.6 | 23.2 | 32.2 | 34.5 |
| June 24 | 2.7 | 7.5 | 11.4 | 20.8 | 2.8 | 10.2 | 14.7 | 27.0 | 32.3 | 38.5 | 66.7 | 66.7 |
| Average | 2.5 | 5.8 | 14.4 | 26.4 | 3.3 | 6.6 | 13.6 | 25.0 | 21.5 | 36.2 | 52.0 | 53.3 |

* Omitted from average.

An experiment was carried out to determine the value of infusions for transmitting the high nitrifying power observed in one sample of soil to another. In Chart IV a great difference is noted in the rate of nitrification, in Soil I between numbers 5 and 8, similarly in Soil II between 13 and 16, and in Soil III between 21 and 24. A series of nitrification tests was arranged in which a comparison could readily be made between the nitrifying power of the different soils and the possibility of transferring this nitrifying power to another soil.



The same laboratory procedure was followed as was used in all our nitrification tests, the results being reported as mgs. N per 100 gms. of soil. It will be readily observed that in no single case did the infusion cause an increase beyond the experimental error. This indicates that the retarding factor which is overcome by liming is not transmitted by inoculation into soil with five to eight cubic centimeters of soil infusions. The infusions were prepared by agitating 25 gms. of soil in 50 c.c. of water. Enough infusion was added to bring the moisture to optimum.

TABLE V. NITRIFYING POWER IS AFFECTED BY INOCULATION

| 5 | 8 | 5 plus infusion from 8 | 13 | 16 | 13 plus infusion from 16 | 21 | 24 | 21 plus infusion from 24 | 5 plus infusion from 24 |
|---|---|---|---|---|---|---|---|---|---|
| 6.6 | 24.4 | 7.1 | 8.2 | 25.6 | 7.4 | 22.2 | 43.5 | 22.4 | 5.3 |

To check further on the nature of the agent which causes the consistent variation between the different soil samples, nitrifications were run in solution using the full set of greenhouse soils in the test. For this purpose the same solution was employed as was used by Voorhees, Lipman, and Brown.[33] Incubation was at room temperature for twenty-

TABLE VI. NITRIFICATION IN SOIL AND SOLUTION

| Soil I | | | | Soil II | | | | Soil III | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Check | 2 T. lime per A. | 4 T. lime per A. | 6 T. lime per A. | Check | 2 T. lime per A. | 4 T. lime per A. | 6 T. lime per A. | Check | 2 T. lime per A. | 4 T. lime per A. | 6 T. lime per A. |
| 2.20* | 3.70 | 9.00 | 14.70 | 2.45 | 4.30 | 10.10 | 17.60 | 11.60 | 23.20 | 32.31 | 34.50 |
| 0.57† | .65 | .68 | .69 | .33 | .57 | .70 | .72 | 2.19 | 2.31 | 2.40 | 2.48 |

*Mgs. N as $NO_3$ per 100 gms. soil.
†Mgs. N as $NO_3$ per 100 c.c. of solution.

eight days. A consistent correlation is apparent between the amounts of nitrate produced in the solutions inoculated with soils which had received the various applications of lime. The variations are slight when compared with the nitrification in the soil. This shows that the agent causing the apparent difference in the nitrification tests in the soil is transmitted by the ten-gram samples of soil used to inoculate the solution, though a narrower ratio exists between the amounts of nitrate produced by them. This would indicate that the application of lime increases the physiological efficiency of the nitrifying organisms; this increase in nitrifying power is subject, however, to the physical and chemical condition of the soil.

These nitrification tests show quite clearly that under greenhouse conditions all three samples of soil give a consistent response to the application of lime. Taking nitrification as a criterion, all three samples would be expected to give crop response.

### Nitrification in Field Soils

There are two possible explanations to account for the action of lime in promoting nitrification: (1) through the improvement of the structure of the soil permitting of more rapid aeration and (2) through the neutralization of toxic properties either chemical or biological. To determine to what extent these conditions are noticeable in field soils, samples were taken on the same type of soil within a very short radius. The purpose of this sampling was to find if any correlation existed between the compactness of the soil, its nitrate content, and its nitrifying power. (It must be taken into consideration that the heavy rains, beginning in November and continuing through the winter, compact the soil and keep it so saturated with water that little or no nitrification can take place. In the spring the soils are leached and devoid of nitrate.) These samples were taken on May 13 after moisture and temperature conditions had become favorable for nitrification to proceed. The samples came from the same locality and were of the same type as Soil I used in the greenhouse tests.

Sample I was from a plot which had been plowed and prepared for seeding. It was in excellent physical condition. This plot is continually cropped to grain, and had been seeded several days before sampling.

Sample II was taken from a clover plot about ten feet from the first sample. No cultivation had been done. This plot had a good stand of clover on it. The rotation was: clover—clover—cultivated crop—small grain.

Sample III was from a bare spot in a plot of winter rye. It had received no cultivation since the planting of the crop.

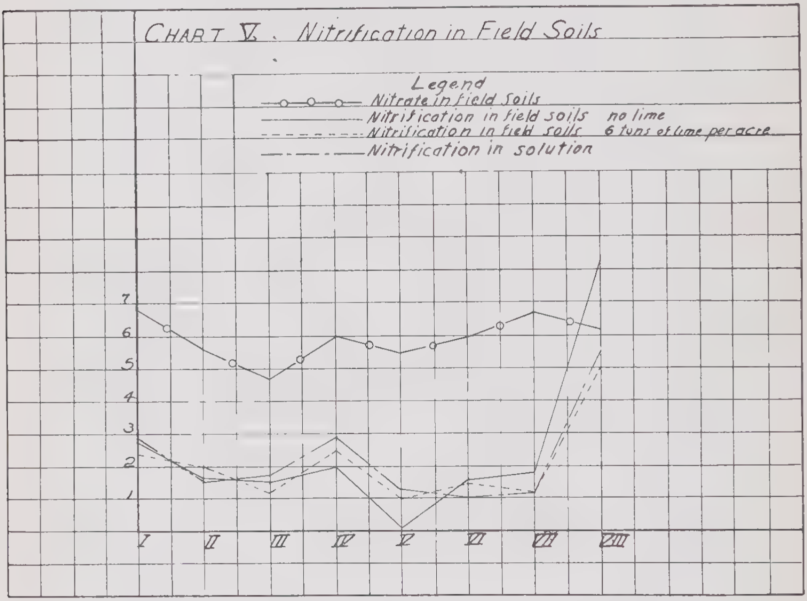
Sample IV was taken between the wheel tracks of the roadway between the plots. The soil was very compact and overgrown with short grass and was drier than the other samples.

Sample V was from the north half of a red clover plot. When seeded to clover one year ago, sulfur was added to the north half and lime to the south half to compare their value in forcing a stand of clover.

Sample VI was from the south side of the clover plot from which sample V was taken. It received one ton of lime per acre one year ago.

Sample VII was taken from the alley between two plots. It is cultivated when the plots are, but is always fallow. Since early spring tillage it had been compacted by the rain and had a hard crust on the surface. The soil was very compact at the time of sampling.

Sample VIII was in excellent tilth. A fine seed bed had just been prepared. The plot had been manured that spring and every four years previously for twelve years. This plot is about two hundred feet from where samples I and II were taken. The rotation as followed on this plot is: manure on corn—small grain—clover—clover.



## TABLE VII. NITRATE FORMATION IN FIELD SOILS

| | | Sample | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VI | VII | VIII |
| | P. P. million of nitrate in field soils | 68.32 | 56.33 | 46.78 | 60.00 | 54.42 | 59.27 | 67.22 | 60.15 |
| Nitrification tests in the laboratory | Mgs. N as $NO_3$ per 100 gms. soil | 2.88 | 1.63 | 1.57 | 2.05 | trace | 1.55 | 1.81 | 8.45 |
| | Mgs. N as $NO_3$ per 100 gms. limed soil* | 23.8 | 2.04 | 12.05 | 25.00 | 10.55 | 14.54 | 16.94 | 50.0 |
| | Mgs. N as $NO_3$ per 100 c.c. solution | 2.8 | 1.6 | 1.7 | 2.9 | 1.3 | 1.1 | 1.7 | 5.4 |

*Lime at the rate of 6 tons per acre.

Table VII and Chart V show some very interesting results. The sample containing the least nitrate at the time of sampling was No. III. These results seem to indicate that in this undisturbed soil, nitrification had not yet become marked. This observation seems contradicted when it is compared with sample IV, which was taken from the roadway. This difference is probably explained by the fact that No. IV was covered with grass, the roots of which kept the soil open. Then too, the center of the roadway was higher, hence the firmness and topography protected it from becoming water-logged. This soil warmed up early in the spring and in spite of the compactness of the soil, the protection from leaching and the aeration due to the grass roots made it more favorable for nitrification than the barren field soil. Samples I and VII contained the most nitrate. These soils had been cultivated early in the spring. Sample VIII, though in excellent condition, did not contain as much nitrate as would be expected using its nitrifying power as an indication. This is probably due to the fact that just recently this seed bed had been prepared. Prior to this time the soil had remained fallow since the previous fall.

A correlation is at once observed between the nitrate content of the field soils and their nitrifying power except in the case of sample VIII. It is quite probable that had this soil been cultivated as early as the plots from which samples I and VII were taken, it would have contained a greater quantity of nitrate.

Nitrification tests were run on these samples after lime had been added at the rate of six tons per acre. The graph representing these results shows clearly that the same general correlation still existed between the nitrifying power of the various samples. It seems evident that though the nitrifying power was increased about ten times, the agent causing the variations (chemical, biological, or physical) is not removed at once by the application of lime. The wide variations have been lost, and it is possible that were these various samples held in contact with the lime under favorable conditions for a longer period of time the graph showing the results would closely approach a straight line.

### Non-Symbiotic Nitrogen Fixation

It will be readily seen from Table VII that on all three soils there is a marked increase in the non-symbiotic nitrogen-fixing power, showing conclusively that the soils in this experiment respond as do those reported by other investigators. These were really anticipated because the writer has experienced considerable difficulty in isolating cultures of Azotobacter from Soil I. This is probably due to the acid reaction of this soil.

TABLE VII. NITROGEN FIXATION

Average percent N.

| Date | Jar<br>5 | 6 | 7 | 8 | 13 | 14 | 15 | 16 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug. 13 | .177 | .145 | .172 | .183 | .143 | .155 | .137 | .157 | .175 | .180 | .170 | .180 |
| Sept. 17 | .165 | .162 | .169 | .180 | .127 | .143 | .140 | .140 | .173 | .177 | .168 | .169 |
| Oct. 14 | .169 | .144 | .170 | .165 | .143 | .135 | .133 | .147 | .166 | .172 | .173 | .185 |
| Jan. 20 | .167 | .171 | .165 | .165 | .135 | .135 | .133 | .137 | .177 | .181 | .176 | .182 |
| Average | .169 | .155 | .169 | .173 | .137 | .142 | .136 | .145 | .173 | .177 | .172 | .179 |

### Influence of Lime on the Growth of Clover

Each jar contained twelve plants. These jars were all inoculated by washing the bacteria off a two-acre-size bottle of inoculating bacteria for clover into a sprinkling can which was used to irrigate the plants. Observations at the time of sampling showed the roots in every jar to be covered with nodules.

Table VIII shows the yields in dry matter in grams of green forage. It will be observed that on Soil I having a lime requirement of 5,000 lbs.

TABLE VIII. EFFECT OF LIME ON THE YIELD OF CLOVER IN THE GREENHOUSE

| | Soil I | | | | Soil II | | | | Soil III | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 T. lime | 2 T. lime | 4 T. lime | 6 T. lime | 0 T. lime | 2 T. lime | 4 T. lime | 6 T. lime | 0 T. lime | 2 T. lime | 4 T. lime | 6 T. lime |
| 1st planting | 22.4 | 28.4 | 31.4 | 25.1 | 25.2 | 26.6 | 30.1 | 24.2 | 29.4 | 27.2 | 26.0 | 29.5 |
| 2nd planting | 18.6 | 26.2 | 26.7 | 22.1 | 23.5 | 27.3 | 32.0 | 22.4 | 31.2 | 31.7 | 25.7 | 32.1 |

(Veitch), the yield of clover was increased by the application of lime up to four tons, but beyond this point a depressing effect was noted. Soil II gives similar results. This soil had a lime requirement of 1400 pounds (Veitch). These are the two samples of soil commonly reputed to give no response to field applications of lime. In the case of Soil III a depressing effect is noted with the application of either 2 or 4 tons of lime per acre. Application of 6 tons did not seem to have the same depressing effect but gave a yield equal to the check. This soil had a lime requirement of 2,000 pounds (Veitch). It was taken from a field that had previously been limed and had shown remarkable crop response. Since it had been limed in the field, it would not be expected to show such great crop response to a new application of lime. From the evidence furnished, this soil gave a crop response quite like Soil II reported by Voorhees, Lipman, and Brown.[33] In the red shale soil they found a depressing effect from the application of either magnesian or non-magnesian lime. The fact that both Soil I and II showed marked increase in crop producing power after applying lime, cannot be taken as accidental because the weights of the crops represent two different plantings extending over a period of one and one-half years. There is the possibility that so great a crop response may not be obtained in the field because the adverse moisture and climatic conditions encountered in the field were eliminated by carrying out this experiment in the greenhouse. The results, however, can be taken as an indication of the value of lime in the growing of clover on these types of soil. The exact rate of application and monetary returns to expect are purely matters for field experments to establish.

To make this investigation more complete, it will be necessary to analyze the soils and crops from the jars to determine the effect of lime on the amount of nitrogen fixed by red clover. Several crops should be grown and an analysis made after each cropping before definite statements are made.

## THE EFFECT OF LIMING ON THE ACIDITY OF THE SOIL

At the beginning of this experiment the lime requirements of these soils were determined by the Veitch method. Soil I showed a lime requirement of 5000 pounds per acre. Soil II had a requirement of 1430 and Soil III of 2145 pounds per acre. After the soils had been treated with lime and incubated for one year samples were taken. Measurements were made of the H-ion concentration by the colorimetric method suggested by Gillespie and Hurst.[17] These results bring up again the question of the value of soil acidity methods. We realize that the growth of plants is more logically associated with the degree of ionization than the titrable acidity. This relation has been clearly shown by

TABLE IX. EFFECT OF LIME AND CROP ON pH VALUE OF SOILS

| Treatment | | 0 tons of lime per acre | 2 tons of lime per acre | 4 tons of lime per acre | 6 tons of lime per acre |
|---|---|---|---|---|---|
| | | pH value | pH value | pH value | pH value |
| Soil I | cropped | 6.2 | 6.2 | 6.6 | 7.2 |
| | fallow | 5.4 | 5.8 | 6.4 | 7.0 |
| Soil II | cropped | 6.2 | 6.6 | 6.8 | 7.2 |
| | fallow | 5.4 | 6.2 | 6.6 | 7.0 |
| Soil III | cropped | 7.0 | 7.4 | 7.5 | 7.5 |
| | fallow | 6.6 | 6.2 | 7.2 | 7.2 |

the work of Salter and McIlvaine.[30] These investigators found that wheat, corn, soy-beans, and alfalfa gave their maximum growth in slightly acid solutions. Reactions of pH3 or lower were found decidedly toxic to all crops and a reaction of pH7 was decidedly less favorable than pH6. Germinating seed was less sensitive to the reaction than the subsequent growth of the plant, there being little difference between pH3 and pH8. The effect of reaction on plant growth largely involves two factors; namely, the effects on the plant and on the soil organisms, especially on those responsible for the changes in soil nitrogen. For red clover, the highest acidity permitting successful inoculation was found to be pH5 and for alfalfa pH6. As shown in Table VIII, 6 tons of lime per acre on both Soil I and II had a decidedly depressing effect on the yield of clover when compared with the smaller applications of lime. This is in keeping with the results reported by Salter and McIlvaine, who report that pH7 is decidedly less favorable than pH6. The fact that a similar depressing effect does not appear with Soil III may be because all the cropped soils had a less hydrogen-ion concentration than pH 7.0.

## FIELD STUDIES ON THE EFFECT OF LIME ON THE NITRATE CONTENT AND NITRIFYING POWER OF WILLAMETTE SILTY CLAY LOAM

The foregoing laboratory and greenhouse results indicate that these soils do respond to the application of lime. To the extent that the methods employed give an index of soil fertility these results might be expected to apply to field conditions. To check more carefully on the conditions governing the behavior of soils toward the application of lime field studies were made. These studies were all confined to Soil I, which is Willamette silty clay loam, the plots of the Agricultural Experiment Station being utilized.

For this study the Soils department through Professor W. L. Powers released four plots lying adjacent to each other that had been cropped continuously to grain for eight years without any fertilizer being applied. These plots are 1/10 acre in size and of uniform properties.

The nitrate content of samples taken from these plots during the years 1923 and 1924 is shown in Table X. Each observation is the result of two composite samples taken simultaneously from the plot, separate analyses being made on each sample and an average being taken of the two determinations.

TABLE X. PARTS PER MILLION OF NITRATE IN FALLOW PLOTS

| | April 13, 1923 | June 11, 1923 | June 27, 1923 | July 11, 1923 | July 26, 1923 | Aug. 8, 1923 | Nov. 5, 1923 | Mar. 19, 1924 | April 23, 1924 | May 26, 1924 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 lime | 1.7 | 9.2 | 8.6 | 15.0 | 12.7 | 9.7 | 14.1 | 1.3 | 3.1 | 8.0 |
| 2 T. lime per acre | 3.2 | 8.8 | 7.4 | 14.1 | 8.1 | 14.8 | 23.3 | 2.1 | 3.5 | 6.0 |
| 4 T. lime per acre | 3.4 | 14.7 | 10.7 | 13.6 | 23.3 | 16.1 | 18.6 | 2.6 | 5.5 | 12.3 |
| 6 T. lime per acre | 4.1 | 17.8 | 12.3 | 22.5 | 19.9 | 29.2 | 26.1 | 3.2 | 7.8 | 12.8 |

Despite the fact that these soils were giving low yields of grain due to constant cereal cropping with no fertilizer being added, it is very apparent that lime stimulated the formation of nitrates from the organic matter present in the soil. Simultaneously samples were being taken from about twelve cropped soils of the rotation series. These soils represented many fertilizer treatments, but never more than a trace of nitrate could be found in these soils during the growing season. Nitrification tests on these fallow plots are just as striking as those reported on the greenhouse soils.

TABLE XI. NITRIFICATION TESTS ON FALLOW PLOTS

Parts per million

| | April 23 | May 26 | June 11 | Average |
|---|---|---|---|---|
| 0 T. lime | 26.6 | 23.0 | 4.2 | 17.9 |
| 2 T. lime per acre | 34.8 | 27.8 | 7.3 | 23.3 |
| 4 T. lime per acre | 154.0 | 58.8 | 95.2 | 102.7 |
| 6 T. lime per acre | 334.0 | 67.8 | 198.0 | 199.9 |

The above data naturally lead one to conclude that lime does stimulate the production of nitrates in the field as well as in the greenhouse. It must be remembered, however, that a deep mulch was maintained on these fallow soils, which was responsible for maintaining the soil at a very favorable moisture content. At the same time the soils on the cropped plots were practically bone dry before the crops reached maturity.

## CLIMATIC FACTORS WHICH INFLUENCE THE BEHAVIOR OF PLANTS

The management of the soils of the Willamette Valley presents a very difficult problem. Forty inches of rainfall annually would naturally classify this as a humid region. The distribution of this rainfall, however, does not coincide with the growing season. The following figures from the Corvallis Station show the mean rainfall for each month for the years 1889 to 1920 inclusive. Irrigation experiments at the Corvallis Station indicate that irrigation would be profitable for most crops.

TABLE XII. AVERAGE RAINFALL AT CORVALLIS STATION FOR 30 YEARS

| Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6.96 | 5.55 | 4.54 | 2.78 | 2.08 | 1.25 | .37 | .40 | 1.79 | 2.85 | 7.10 | 6.96 | 42.46 |

Due to the peculiar climatic and soil conditions of the Willamette Valley no general conclusions can be drawn, nor a system of management adopted based on observations from other parts of the country. The soils are generally heavy and acid in reaction. During the winter months much of the lowland is water-logged, and the soils become compact and puddled. When spring comes the rains cease, and within a very short time moisture is the limiting factor. The period of optimum moisture and temperature is so short that biological activities within these soils cannot function in making the maximum amount of plant food available for the crops. These facts are illustrated by the observations recorded in Table XIII, which are the moisture content and soil temperatures of a well drained, uncropped plot of Willamette silty clay loam at different times of sampling during the growing season of 1922.

TABLE XIII. MOISTURE AND TEMPERATURE RELATIONS IN A FIELD SOIL DURING THE GROWING SEASON

| Date | Mar. 20 | April 4 | April 18 | May 9 | May 23 | June 15 | July 7 | July 26 | Aug. 16 | Sept. 22 | Oct. 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature °C. | 9.5 | 8.7 | 8.0 | 9.3 | 14.0 | 24.0 | 23.5 | 22.3 | 21.3 | 21.3 | 13.0 |
| Percent moisture (air dry basis) | 34.1 | 30.5 | 30.3 | 28.1 | 23.2 | 13.5 | 3.9 | 5.9 | 10.9 | 6.1 | 15.2 |

Since these soils are leached to such an extent every winter and the ensuing summer drought shortens the period of maximum biological activities, it will be readily seen that the maintenance of the fertility of these soils is a difficult problem. The soils are acid in reaction, yet there is much diversity of opinion among investigators and laymen as to the value of lime as a soil amendment on clover, wheat, and other staple crops. This division of opinion also holds true for phosphorus and other fertilizers, though certain soil types have been segregated on which the value of both lime and phosphorus has been demonstrated. Gypsum seems to be the only commercial fertilizer that has met with widespread approval.

## ACKNOWLEDGMENTS

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Experiment Station

# Pollination and Growing of the Cherry

By

C. E. Schuster

1885

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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# SUMMARY

In pollination work on the cherry, emasculating the flowers and leaving them exposed to the open is preferred to sacking the flowers.

Pollen was taken from the flower by rubbing the flower over a piece of window screen.

Prompt pollination, as soon as the flowers are receptive, gives the best results.

Bing, Lambert, and Napoleon are self-sterile and intersterile. Intersterility is common among the sweet cherries.

Pollenizers for sweet cherries can not be recommended in general by varietal name. It is necessary to designate specific trees or groups of trees of proved worth.

Performance in the field is a good check as to value of pollenizers.

Growers can test their own materials by use of limbs of flowers.

Sour cherries are not satisfactory for pollination of sweet cherries.

Temperature affects the flight of insects, thus affecting the distribution of pollen and ultimately the crop. Use one hive of bees to one or two acres of trees.

One tree in nine is recommended as a pollenizer.

Using whole trees as pollenizers is usually preferable to one limb to a tree.

The sour cherry may be self sterile, self fertile or partly self-fertile, depending on the variety.

The Montmorency, so far as tested, is self sterile but may be cross-pollinated by Early Richmond or English Morello.

Plant sweet cherries on deep, fertile, well-drained soils 30 to 40 feet apart; sour cherries 25 to 30.

Maintain fertility in the soil by cover cropping.

Use Mazzard seedlings for the trunk and scaffold branches where gummosis is destructive.

Prune the tree from the beginning, but do little heading after the first few years.

Heavy cropping will help in keeping the trees low.

Cultivate steadily and thoroughly.

Pick the cherries when ripe and handle carefully. If shipping fresh, cool promptly.

# Pollination and Growing of the Cherry

By

C. E. SCHUSTER

## A. POLLINATION OF THE CHERRY

### INTRODUCTION

At the time the sweet cherry was first introduced into the Pacific Northwest there was little thought of growing cherries other than for home use. When Llewelyn introduced the Napoleon along with other varieties, the trees were planted to provide a succession of cherries throughout the cherry season that would be suitable for home consumption. With the introduction of the Bing and Lambert varieties, and the development of refrigerator cars, came the idea of shipping these cherries in a fresh state to the distant markets. In order to do this, large acreages of these varieties were required in order to make up car-load shipments. In the plantings put out after this time the common or poorer varieties, like the Black Republican, Black Tartarian, Governor Wood, Major Francis, etc., were omitted, as their general quality was so much inferior to the three main varieties that it was thought useless to waste the ground with them. As a consequence, the plantings consisted of either Bing, Lambert, Napoleon, or a combination of these three. In the small miscellaneous plantings around the homes, these varieties were productive, but in the special plantings the crops were uniformly poor.

Many causes were ascribed for this non-productiveness, but it was definitely shown by Gardner in 1913 that the sweet cherry was self-sterile, and he also established the fact that the Bing, Lambert, and Napoleon were intersterile. At the same time the value of cross-pollination for these varieties was proved experimentally.

A survey of the orchards showed that those orchards of Bing, Lambert, or Napoleon, or those with these varieties in varying proportions, that were bearing well, always had either seedlings or secondary varieties scattered throughout the orchard. By accident or otherwise, the nurserymen had provided a few growers with combinations of varieties that were shown to be heavy producers when planted together. As the result of these observations and the experiments, many orchardists had the recommeded varieties grafted into a certain number of the trees, in order to provide cross-pollination.

At the end of four or five years, when it was anticipated that the yields of these orchards should be rapidly increasing, observations in many cases showed that no increase was to be found. This was puzzling and caused doubt to be thrown upon the efficiency of the varieties that had been urged as valuable for cross-pollination purposes. The grafts were blooming heavily, but no increase could be noted in the yield of the surrounding trees.

In 1922 the Chamber of Commerce of The Dalles, Oregon, urged through the county agent that additional work be done to correct the light bearing of the orchards in that section. It was estimated that not more than 40 to 60 percent of a crop was being obtained in the district as a whole. Work was started that season, and carried on through 1922, 1923, and 1924.

In the meantime, results from the John Innes Horticultural Station had been published in 1923 by M. B. Crane.[2] These results showed that the sweet cherry of England was self-sterile, and that some crosses were more successful than others. Crane also brought out that the sour cherry was not always self-fertile, but in the case of certain varieties was entirely self-sterile.

Rudolf Florin,[3] of Sweden, recounts the same results in the pollination of the sweet and sour cherries of Sweden, and also brings out the fact that there is more than one kind of sour cherry being grown under one varietal name in Sweden. Cherries with the same name vary in the pollination tests, one being self-sterile and another entirely self-fertile. Philp,[4] of California, reports the same conditions in California. Different strains or types of one variety are to be found, some of which are effective in cross-pollination, while others are useless. Results may vary from year to year.

## OUTLINE OF WORK

In 1922 pollination work was started in the vicinity of The Dalles, Oregon. The object was to determine the varieties best suited to interplant as pollenizers with the Bing, Lambert, and Napoleon. The points considered in the selection of these varieties were:

1. They must be able to cross-pollinate with the commercial varieties, setting heavy crops of cherries on these three varieties.
2. They must bloom at the same time as the commercial varieties.
3. They must produce heavy bloom, with abundant, viable pollen.
4. If possible, the fruit should have a market value.

The first three are essential characteristics of a variety that is to be used in cross-pollination, while the fourth is desirable.

## METHODS EMPLOYED

The methods used in the experiments varied, and will be recounted as used. The different methods affected the accuracy and speed of the work in one or more ways, so that they will be listed below.

**Sacking and emasculation.** During the first year all blossoms were emasculated by nipping the corolla just below the point of the attachment of the stamens (Fig. 1). The corolla, with the stamens, was pulled off, leaving the pistil exposed. Whenever emasculation was used it was tantamount to a thinning of the blossoms, as not all the blossoms mature at the same time. Some of the blossoms of a limb or tree would be fully in bloom, while others might not even be showing any white of the petals. This irregularity was especially noticeable in the Bing and Napoleon. It was necessary to thin out a certain number of blossoms in order to obtain the ones at the proper stage for emasculation, which was just before the petals opened out.

After the emasculation the blossoms were sacked. In this and previous work, sacking has proved unsatisfactory. With the pistil envery light frost that would do no damage to blossoms exposed to the open, the pistils that came in contact with the paper of the sack were killed. The other extreme was found during the hottest part of the day, and very warm days sometimes do occur during blooming season. In addition to these sources of damage, many pistils were injured by the sacks swaying in the wind. Altogether it was considered that sacking of the flowers was producing poor results, and there was no means to determine the actual damage incurred in each sack. The variation possible from this cause might have been reduced by using large numbers of sacks, but the numbers necessary would have been so large that it would have been impossible to carry on the pollination work with all the varieties that it was desired to test out. Table I shows the variation in individual sacks in which the cross-pollination work was done at approximately the same time and from the same bottle of pollen.

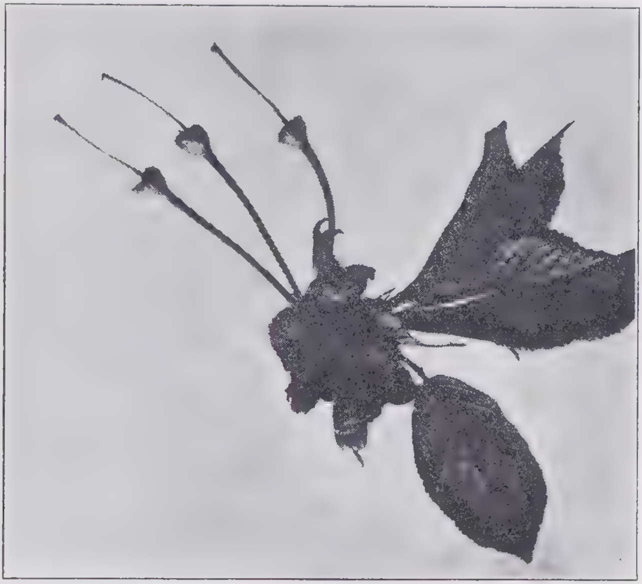

Fig. 1. Flowers emasculated. In the later work the flowers were left exposed in this condition without covering. With the petals removed there was no attraction for the insects therefore no transfer of pollen.

During the second season the flowers were emasculated and left uncovered. It was with the idea that since the flowers were without the white petals, no insect would be attracted, and thus there would be no danger of bringing about cross-pollination. Table II gives the percentage of fruit set where the pistils were left exposed for insect pollination, and were without hand pollination as compared to those not emasculated and pollinated by insects.

TABLE I. VARIATION FOUND IN DIFFERENT SACKS IN CROSS-POLLINATION DURING 1922

| | Number of blossoms | Number of sacks | Highest percentage set in any one sack | Lowest percentage set in any one sack |
|---|---|---|---|---|
| | | | % | % |
| Lambert | | | | |
| X Black Republican | 829 | 18 | 100 | 13 |
| X Major Francis | 537 | 15 | 100 | 17 |
| X Early Purple | 1053 | 17 | 86 | 2 |
| Napoleon | | | | |
| X Centennial | 535 | 9 | 42 | 5 |
| X Black Republican | 534 | 11 | 63 | 13 |
| X Black Oregon | 462 | 24 | 55 | 0 |
| Bing | | | | |
| X Norma | 516 | 11 | 65 | 2 |
| X Black Tartarian | 711 | 12 | 62 | 0 |
| X Governor Wood | 501 | 12 | 51 | 0 |

TABLE II. BLOSSOMS EMASCULATED AND LEFT EXPOSED AS COMPARED WITH THOSE NOT EMASCULATED. BOTH OPEN TO CROSS-POLLINATION BY INSECTS

| | 1923 | | | | 1924 | | | |
|---|---|---|---|---|---|---|---|---|
| | No. of flowers emasculated | Percent set | Insect pollinated | Percent set | No. of flowers emasculated | Percent set | Insect pollinated | Percent set |
| | | % | | % | | % | | % |
| Napoleon | 467 | 0 | 4429 | 10.1 | 206 | 0 | 1752 | 42.1 |
| Bing | 1625 | .8 | 4143 | 7.0 | -------- | ---- | 1118 | 17.8 |
| Lambert | 680 | 1.7 | 3087 | 6.0 | 1140 | 1.2 | 2713 | 40.0 |

As the cherry had proved self-sterile in 1922, many blossoms in 1923 were sacked without emasculating. This method, however, made very slow work in cross-pollination, and was open to the same objection as when the flowers were emasculated and then sacked.

During the third season the flowers were emasculated and left open as during 1923. This method does not allow for as much time to carry on the cross-pollination as when the flowers are sacked. Drying winds and other unfavorable climatic conditions may make the pistils much shorter lived than when enclosed in sacks, unless those in sacks are subject to frosty conditions, when the danger of killing is increased for those in the sacks. Due to the increased accuracy of the results and the amount of material that can be worked with, the system of emasculation and leaving exposed to the open was considered the best for use with the cherry.

**Gathering pollen.** Pollen was gathered just after the blossoms opened. At this stage the anthers would seldom be found to have burst. The anthers at first were raked out of the flower with a fine-toothed comb. Later it was found that by brushing the flower over a square of window screen the anthers would snap off and fall through the screen into a dish placed below. With the right pressure very few of the filaments would be collected with the anthers.

After collection, the anthers were dried in a shallow dish, where they would burst and shed the pollen. The pollen was left in open dishes until thoroughly dried, and then put into bottles, stoppered lightly with cotton. Any tight container might cause fermentation; and pollen tightly enclosed in a container, even though dry, seems to deteriorate rapidly in its vitality.

**Germination of pollen.** Pollen was tested for germinability in artificial media, consisting of 12 percent sugar and about 1 percent of gelatine. This material on the whole gave the best results, but was not entirely satisfactory. In 1922-23 pollen showing germination of less than 50 percent was discarded. The pollen grain was counted as having germinated if the pollen tube projected far enough from the pore to be recognized as a tube, even though later it should burst. Table III gives the percentage of germination of the pollen used in 1924.

TABLE III. GERMINATION OF POLLEN USED AT THE DALLES (1924)

| | Variety of pollen | Germination |
|---|---|---|
| No. 1 | Black Republican | 96 |
| No. 2 | Centennial | 80 |
| No. 3 | Centennial | 85 |
| No. 4 | Black Republican | 82 |
| No. 5 | Black Republican | 61 |
| No. 6 | Black Republican | 93 |
| No. 7 | Black Tartarian | 79 |
| No. 9 | Black Republican | 89 |
| No. 10 | Long Stemmed Waterhouse | 45 |
| No. 11 | Black Oregon | 72 |
| No. 12 | Norma | 86 |
| No. 13 | Norma | 92 |
| No. 14 | Abundance | 88 |
| No. 15 | Long Stemmed Waterhouse | 75 |
| No. 16 | Black Oregon | 82 |
| No. 17 | Abundance | 85 |
| | Centennial No. 3 (Milton) | 10 |
| | Black Tartarian (Milton) | 50 |

A series of pollen lots that were sent in for test in this cross-pollinaion work tested low, as noted with Centennial and Black Tartarian from Milton. Although the tests gave a low percentage of germination, some of the pollination results did not correspond. More accurate methods of pollen germination need to be worked out.

**Application of pollen.** Due to the rapidity with which the pollen could be gathered a camel's-hair brush was generally used in applying he pollen. This method is wasteful of pollen, but it seems to be much aster than the other methods and occasions less loss of time in changng from one variety of pollen to another. It was used wherever the ollen was abundant. Enough was applied to the pistils to be visible to he naked eye. When the pollen was scarce it was applied to the pistils with the finger tips, as less loss was occasioned by this means.

The pollen was applied as soon as the pistils showed drops of liquid n the stigma. The author is inclined to apply pollen early rather than ater. Drying winds will at times prevent the appearance of this liquid, nd the pistils that are emasculated and left exposed to the open may e further advanced than appear on casual observation, unless a careful heck is to be had of other protected flowers in the same locality.

The first evidence of a flower being past maturity occurs in a slight reddening of the tissue of the style just above the ovary, at the point where the style is possibly the smallest in diameter. Pollination after this time has generally proved rather unsuccessful, and although the petals might not fall until some time later, it seems that the possibility of fertilization taking place after this point is very much decreased. This reddening of the tissue develops quite rapidly under certain climatic conditions at The Dalles, when the pistils are left exposed, thus reducing the time within which the experiment might be carried on. Since this same condition was noted with other flowers not emasculated, it appears that cross-pollination should be forced as soon as possible.

To test the effect of very early pollination, numbers of flowers were emasculated at the usual stage of development and immediately hand-pollinated. The emasculation and pollination were carried on within one hour and completed at least forty-eight hours before the usual time for cross-pollination. The results are given in Table IV. The results show that the pistils are either receptive before the usual time of opening, or that some of the pollen remains on the stigma and as soon as the pistil becomes receptive, starts germination and growth.

TABLE IV. EARLY VS. REGULAR TIME FOR CROSS-POLLINATION

| | | Early | | Regular | |
|---|---|---|---|---|---|
| | | No. of blossoms | Percent set | No. of blossoms | Percent set |
| | Napoleon X | | % | | % |
| No. 1 | Black Republican | 542 | 9.4 | 909 | 17.4 |
| No. 7 | Black Tartarian | 432 | 6.0 | 530 | 31.3 |
| No. 9 | Black Republican | 208 | 2.4 | 857 | 23.6 |

## STERILITY TESTS

**Self-sterility.** During this work, sterility tests were conducted with the Bing, Lambert, and Napoleon. In 1922 the flowers were simply sacked and the action of the wind depended upon to distribute the pollen. After that year the pollen was placed on the pistils by hand. Results of this work are recorded in Table V. This work corroborated the early work on the pollination of the sweet cherry, as brought out before. An opinion has often been expressed that the sweet cherry may be self-fertile some seasons when conditions may be ideal. This apparent self-fertility, however, is usually connected with certain conditions that will be discussed later.

TABLE V. SELF-STERILITY TESTS

Napoleon, Bing, and Lambert

| | 1922 | | 1923 | | 1924 | |
|---|---|---|---|---|---|---|
| | No. of blossoms | Percent set | No. of blossoms | Percent set | No. of blossoms | Percent set |
| | | % | | % | | % |
| Napoleon | 1624 | .1 | 523 | 3.0 | 255 | .3 |
| Bing | 1003 | .0 | 350 | .8 | 528 | 3.1 |
| Lambert | 1086 | .1 | 858 | 2.3 | ...... | .... |

A common belief has been held that seedlings were self-fertile and especially the more worthless types. Although theoretically there would be no grounds for this belief, as all our varieties supposedly originated as seedlings, this factor was considered in the outline of the work. Records are being kept as to self-sterility of the better seedlings in the cherry seedling plot of the Experiment Station with the hope of finding a self-fertile tree. In this connection, separate tests were also made of some of the very poor seedlings; one in particular having small, black, bitter and astringent fruit. These seedlings behaved in no different way from the better types or some of the varieties as recorded in Table VI.

TABLE VI. SELF-STERILITY OF CHERRY SEEDLINGS

| No. | 1921 |  | 1922 |  |
|---|---|---|---|---|
|  | No. of fruits | Percent set | No. of fruits | Percent set |
|  |  | % |  | % |
| A1 | 235 | 0 | 324 | 0 |
| A2 | 229 | 0 | ------ | -- |
| A3 | 254 | 0 | 264 | 0 |
| A4 | 284 | 0 | ------ | -- |
| A5 | 213 | 0 | ------ | -- |
| A6 | 211 | 0 | ------ | -- |
| A7 | 217 | 0 | ------ | -- |
| A8 | 139 | 0 | ------ | -- |
| A9 | 285 | 0 | ------ | -- |
| A10 | 244 | 0 | 927 | 0 |
| A11 | 224 | 0 | ------ | -- |
| A12 | 255 | 0 | 224 | 0 |
| A13 | 242 | 0 | 288 | 0 |
| A14 | 224 | 0 | 239 | 0 |
| A15 | 249 | 0 | 230 | 0 |
| A16 | 207 | 0 | ------ | -- |
| A17 | 213 | 0 | ------ | -- |
| A18 | 259 | 0 | 219 | 0 |
| A19 | 260 | 0 | ------ | -- |
| A20 | 231 | 0 | ------ | -- |
| A22 | 264 | 0 | 213 | 0 |
| A23 | 200 | 0 | ------ | -- |
| A24 | 231 | 0 | ------ | -- |
| A25 | 96 | 0 | ------ | -- |
| A26 | 173 | 0 | ------ | -- |
| A27 | 154 | 0 | 271 | 0 |
| B9R2T7 | ------ | -- | 467 | 0 |
| R2T1 (Very poor type) | ------ | -- | 318 | 0 |
| R2T2 (Very poor type) | ------ | -- | 287 | 0 |
| Elton R. A. Seedling | ------ | -- | 374 | 0 |
| Seedling (Elton) | ------ | -- | 529 | 0 |
| Black Oregon | ------ | -- | 546 | 0 |

**Intersterility.** These same seedlings mentioned above were used in crossing on the Bing, Lambert, and Napoleon. It will be noticed that the seedlings varied in their reactions on the individual variety, some seedlings being successful with all of the varieties, and others being entirely intersterile. Pollen germination tests are also given in Table VII, and the comparison shows that the failure in most cases can not be attributed to poor pollen.

The possibility of cross-pollination between the Bing, Lambert, and Napoleon was considered again. Table VIII shows the results of three years' tests. While in many cases it was not complete intersterility, it was sterility from a commercial standpoint. This would indicate that cross-pollination between these varieties can not be depended on to produce crops.

TABLE VII. CROSS-POLLINATION TESTS WITH SEEDLINGS ON BING, LAMBERT, AND NAPOLEON

| Seedling number | Percent set on Bing | Percent set on Lambert | Percent set on Napoleon | Percent pollen germinated |
|---|---|---|---|---|
| | % | % | % | % |
| A1 | 0 | 0 | 0 | 92 |
| A2 | 0 | 22 | 24 | 50 |
| A3 | 0 | 0 | 0 | 75 |
| A4 | 8 | 0 | 21 | 10 |
| A6 | ---- | 6 | 1 | 12 |
| A7 | 0 | 0 | 3 | 70 |
| A8 | 11 | 13 | 39 | 80 |
| A9 | 17 | 8 | 17 | 28 |
| A10 | 0 | 31 | 42 | 38 |
| A11 | 8 | 35 | 7 | 61 |
| A12 | 13 | 9 | 54 | 30 |
| A13 | 8 | 5 | 1 | 43 |
| A14 | 6 | 6 | 16 | 8 |
| A15 | 14 | 0 | 5 | 10 |
| A16 | 0 | 0 | 0 | 16 |
| A17 | 0 | 20 | 40 | ---- |
| A18 | 0 | ---- | 0 | 56 |
| A19 | 0 | 0 | 0 | 51 |
| A20 | 4 | 26 | ---- | 60 |
| A23 | 1 | 0 | 30 | 5 |
| A24 | 0 | 0 | 0 | 50 |
| A26 | 16 | 54 | 30 | 43 |

As A3 was crossed with the Napoleon, Bing, and Lambert in these tests, and failed, the reciprocal crosses were tried with this single seedling, because this seedling shows unusual promise in the fruit. Table IX is the result of the reciprocal crosses, showing a group of four varieties of trees intersterile among themselves. This record of intersterility tests on A3, Napoleon, Bing, and Lambert makes a group of four completely intersterile among themselves. From this work in Table VIII and Table IX and that of Gardner, Crane, and Florin, it can be seen that intersterility is not at all uncommon among sweet cherries, but rather that there is a great tendency that way. Later studies will show that varieties vary from intersterility to a high state of interfertility.

TABLE VIII. INTERSTERILITY OF NAPOLEON, BING, AND LAMBERT

| | 1922 | | 1923 | | 1924 | |
|---|---|---|---|---|---|---|
| | No. of flowers | Percent set | No. of flowers | Percent set | No. of flowers | Percent set |
| | | % | | % | | % |
| Napoleon | | | | | | |
| X Bing | 499 | .4 | 500 | 0 | 329 | 2.1 |
| X Lambert | 411 | .2 | 669 | 1.0 | ------ | ---- |
| Bing | | | | | | |
| X Napoleon | 646 | 0 | 650 | 0 | 238 | .4 |
| X Lambert | 470 | 0 | 265 | 3.0 | ------ | ---- |
| Lambert | | | | | | |
| X Bing | 450 | 0 | ------ | ---- | 189 | 1.5 |
| X Napoleon | 869 | 1.3 | 503 | 2.0 | 254 | 1.5 |

No record has been obtained over a period of years to show that absolute self-sterility or absolute intersterility exists, but the set of fruit resulting is so small that it is sterility from the commercial standpoint. An occasional cherry may result from any case of self-pollination or cross-pollination. This might as well be ascribed to an error or to an

TABLE IX. INTERSTERILITY OF A3, BING, LAMBERT, AND NAPOLEON

| | No. of blossoms | Percent set |
|---|---|---|
| | | % |
| Bing | | |
| X A3 | 53 | 0 |
| Napoleon | | |
| X A3 | 70 | 0 |
| Lambert | | |
| X A3 | 43 | 0 |
| A3 | | |
| X Bing | 120 | 0 |
| X Lambert | 152 | 0 |
| X Napoleon | 160 | 0 |

accident as to the tendency of the variety for self-fertility or interfertility.

This characteristic of individual varieties is undoubtedly carried by the Mazzard seedlings. Observations in the field will show that some Mazzard seedlings are setting a crop on the surrounding Bing, Lambert, or Napoleon trees, while others fail entirely.

## SELECTION OF POLLENIZERS

Since the sweet cherry is self-sterile and shows considerable intersterility, the big problem was to find the best material for cross-pollination purposes with the Bing, Lambert, and Napoleon.

**Results of 1922-23.** In 1922 cross-pollination work was carried on in the usual manner. Reciprocal crosses were made in some cases, but in the light of later work have not been included. The pollen was selected in widely divergent places, so that distances made it impractical to do much of this type of work. In addition the elevation in some districts made such a difference in the blooming dates that it was often impossible to carry on the work. The varieties first used in cross-pollination have, under Oregon conditions, little or no commercial value. This fact will be discussed later. Results are listed in Table X.

TABLE X. RESULTS OF CROSSES MADE ON BING, LAMBERT, AND NAPOLEON AT THE DALLES, OREGON, 1922

| | Bing | | Lambert | | Napoleon | |
|---|---|---|---|---|---|---|
| | No. of blossoms | Percent set | No. of blossoms | Percent set | No. of blossoms | Percent set |
| | | % | | % | | % |
| Montmorency | 329 | 0.9 | 490 | 20.2 | 401 | 15.2 |
| Early Richmond | 630 | 2.0 | 800 | 12.0 | 634 | 1.1 |
| May Duke | 527 | 4.7 | 176 | 3.4 | 547 | 3.1 |
| Black Republican | 543 | 6.9 | 829 | 38.4 | 534 | 34.8 |
| Early Purple | 629 | 6.6 | 1053 | 51.8 | 769 | 19.5 |
| Long Stemmed Waterhouse | 466 | 9.4 | 140 | 43.5 | 474 | 17.0 |
| Elton Seedling | 609 | 7.5 | 839 | 12.5 | 582 | 1.0 |
| Coe | 478 | 11.2 | 507 | 58.5 | 513 | 36.8 |
| Black Oregon | 1135 | 12.1 | 1075 | 66.5 | 462 | 23.1 |
| Major Francis | 517 | 18.5 | 537 | 51.3 | 439 | 28.4 |
| Centennial | 893 | 23.7 | 850 | 34.1 | 535 | 24.1 |
| Governor Wood | 501 | 23.1 | 498 | 29.5 | 599 | 26.5 |
| Early Rose | 504 | 29.6 | 525 | 39.0 | 544 | 21.6 |
| Elton | 538 | 31.5 | 902 | 66.4 | 463 | 28.7 |
| Black Tartarian | 711 | 35.7 | 520 | 47.5 | 507 | 11.8 |
| Norma | 516 | 40.8 | 531 | 33.3 | 602 | 40.8 |

TABLE XI. RESULTS OF CROSSES MADE ON BING, LAMBERT, AND NAPOLEON AT THE DALLES, OREGON, 1923

| | Bing | | | | Lambert | | | | Napoleon | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sacked but not emasculated | | Emasculated but not sacked | | Sacked but not emasculated | | Emasculated but not sacked | | Sacked but not emasculated | | Emasculated but but not sacked | |
| | No. of blossoms | Per-cent set | No. of blossoms | Per-cent set | No. of blossoms | Per-cent set | No. of blossoms | Per-cent set | No. of blossoms | Per-cent set | No. of blossoms | Per-cent set |
| | | % | | % | | % | | % | | % | | % |
| Montmorency | ---- | ------ | 394 | 39.8 | 122 | 49.1 | 455 | 49.2 | 116 | 64.6 | 230 | 14.7 |
| Early Richmond | 65 | 3.0 | 819 | 21.1 | 48 | 16.6 | 598 | 50.6 | 212 | 48.1 | 212 | 17.9 |
| May Duke | 66 | 27.2 | 412 | 27.9 | 84 | 54.7 | 563 | 60.0 | 127 | 59.8 | 467 | 18.6 |
| Black Republican (OAC) | 63 | 38.0 | 548 | 43.9 | 83 | 79.5 | 563 | 58.0 | 204 | 52.8 | ------ | ------ |
| Black Republican (Collins) | ---- | ------ | 521 | 32.4 | 86 | 72.0 | 639 | 52.7 | 44 | 70.4 | 374 | 57.4 |
| Long Stemmed Waterhouse | 81 | 48.1 | 747 | 31.1 | 166 | 80.1 | 779 | 73.1 | 124 | 91.1 | 732 | 34.6 |
| Coe | 23 | 60.8 | 1003 | 42.9 | 77 | 53.2 | 790 | 82.9 | 136 | 71.2 | 553 | 40.5 |
| Black Oregon | 31 | 64.5 | 1031 | 43.9 | 121 | 63.6 | 510 | 69.0 | 208 | 83.1 | 482 | 25.7 |
| Major Francis | 45 | 6.6 | 542 | 42.9 | 99 | 50.5 | ------ | ------ | 344 | 59.3 | 670 | 13.7 |
| Centennial (Becker) | 53 | 71.6 | 500 | 58.6 | 67 | 59.6 | 230 | 56.5 | 97 | 47.4 | 441 | 25.1 |
| Centennial (Davis) | ---- | ------ | 758 | 55.9 | ------ | ------ | 123 | 59.3 | 280 | 60.3 | 279 | 24.7 |
| Governor Wood | --- | ------ | 545 | 62.2 | 74 | 62.1 | 255 | 77.6 | 136 | 63.2 | 127 | 24.4 |
| Early Rose | ---- | ------ | ------ | ------ | ---- | ------ | 299 | 92.3 | 317 | 73.5 | 462 | 37.4 |
| Abundance | 78 | 46.1 | 260 | 36.9 | 98 | 75.5 | 250 | 75.2 | 138 | 55.7 | 717 | 39.1 |
| Black Tartarian (Williams) | 39 | 53.8 | 250 | 51.2 | 79 | 60.6 | 302 | 76.1 | 182 | 88.0 | 243 | 22.2 |
| Black Tartarian (Milton) | ---- | ------ | 546 | 38.2 | ---- | ------ | ------ | ------ | 57 | 66.6 | ------ | ------ |
| Norma | 76 | 36.9 | 947 | 41.9 | 137 | 74.4 | 784 | 73.5 | 111 | 55.8 | 827 | 26.1 |
| Elton | 56 | 41.0 | 488 | 50.8 | ------ | ------ | 177 | 59.3 | ------ | ------ | ------ | ------ |

In 1923 the methods were changed. Most of the work was done by emasculating the flowers, and leaving them exposed. As the sweet cherry is self-sterile, many blossoms were also simply enclosed in sacks without emasculation. Being self-sterile there was no danger of the pollen of the same varieties setting any fruit. A study of Table XI shows the variation between the two methods employed that season. In the case of Napoleon, one tree used during the first day of the pollination work and supposed to be Napoleon, was found later to be another variety. Much of the work on the Napoleon was lost, therefore, and the remainder of the work was performed on the flowers left exposed for some time, and which apparently finished their life cycle more quickly than those enclosed in the sacks. That may be the reason for the lower set of fruit in those flowers emasculated and left exposed as compared with the same results with the Bing and Lambert.

A comparison of results of 1922 and 1923 shows the variation between the two seasons. In the main those that were successful the first year were also successful in the second year, but the order of greatest efficiency was not maintained.

While the experimental results were satisfactory, the reports from growers showed negative results with the same varieties. An investigation showed that in some cases it was quite evident that the variety the grower had in his orchard was not the same that had been used in the experimental work, though it was called by the same name. In other cases it was impossible to state definitely that it was, or was not, the same variety. Experience with fruiting cherry seedlings in a planting in which new seedlings greatly resembling or practically identical with the old varieties were often noted, makes one more cautious in an absolute identification.

In time it may be possible to work out identification points that will enable any person expert in that line to identify absolutely any variety. On the other hand, the minor differences would probably be so fine or delicate that the average person could not use them, or if using them would badly confuse the different points so that the identification would be useless.

This mixed-up nomenclature is not confined wholly to the secondary or pollenizing varieties, although the greatest discrepencies seem to occur in the secondary varieties. In the main varieties also this confusion undoubtedly occurs. In The Dalles district there are two distinct types of Royal Anns or Napoleons, and undoubtedly more exist in other parts of the state. From the standpoint of excellence of fruit, there is no loss to the grower, but this confusion puts difficulty in the way of effective cross-pollination. While the identification of the individual varieties is being worked out, other means were sought to correct the condition as now found in this state.

**Certification of trees in 1924.** In 1924 it was decided to discard the previous results, except as to their value in indicating the direction in which the experiment should be carried on. The season's work was divided into two parts:

(1) Providing certified wood for propagating young trees for new plantings. In this it would be necessary to certify as to the compatability of the pollenizing varieties, and the individual trees of the main varie-

ties. The work would necessarily have to be with individual trees that would furnish the propagating wood.

(2) Providing a plentiful supply of grafting wood for top-working trees in old orchards that had no pollenizers. This was for general use with the established orchards, but could only be certified to that it was of a variety that was satisfactory for cross-pollination on those trees that were used in this work.

For the most part the pollenizers selected were from those orchards having good production yields (Fig. 2). In a few cases, trees were selected where the fruit apparently had a commercial advantage over fruit of those varieties commonly found. It was not so much an attempt to discover the ideal commercial varieties to combine with the Bing, Lambert, or Napoleon, as it was to find available material that could be used to increase the yields of the mature orchards now deficient in production and to guarantee heavy yields to the new plantings of Bing, Lambert, and Napoleon being made at the present time. If this could be done, a step in advance had been taken. Orchards were being rapidly planted and old, mature orchards were idle so that the pressing problem was as stated above. The locating or developing of the ideal pollenizers is probably a matter for the future.

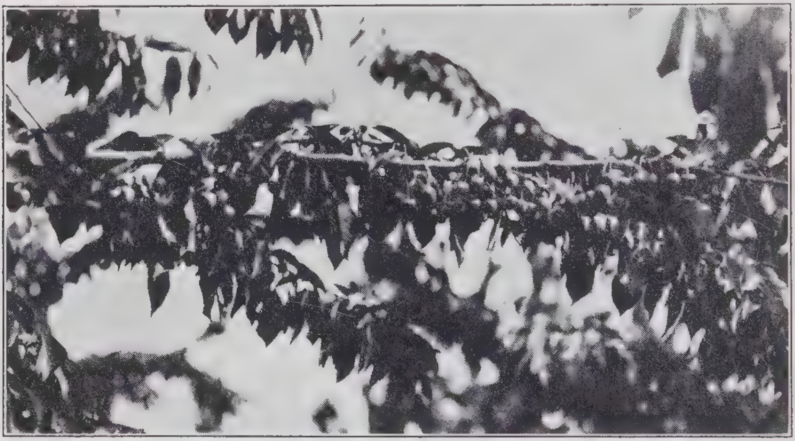

Fig. 2. An average limb of fruit in an orchard where pollenizers were abundant and bees were placed in the orchard. Black Republicans made up 25 percent of the planting.

Table XII shows the results of the work of 1924. There is variation in the efficiency of the different lots of pollen of the same variety. This cannot be considered very heavily against any one lot, provided the set of fruit recorded would, under natural conditions, provide a commercial crop. The set from the artificial pollination this year was not as heavy as in 1923, but the natural set was much heavier.

A test over a period of years might show that the difference in range of percentage of fruit set as indicated in the tests this year would be an advantage for certain varieties. Until it is possible to control nutrition, moisture, climatic conditions, and other factors affecting plant growth, too much dependence cannot be placed on a small difference even if repeated throughout several years. Changing varieties to other locations or positions might change the relative efficiency of the different varieties.

TABLE XII. RECORD OF INDIVIDUAL TREES IN CROSS-POLLINATION TESTS WITH BING, LAMBERT, AND NAPOLEON IN 1924

| | No. of blossoms | Percent set |
|---|---|---|
| | | % |
| Napoleon X | | |
| No. 2 Centennial | 530 | 16.6 |
| No. 3 Centennial | 870 | 14.3 |
| No. 1 Black Republican | 909 | 17.4 |
| No. 4 Black Republican | 816 | 26.8 |
| No. 5 Black Republican | 769 | 25.1 |
| No. 6 Black Republican | 435 | 28.0 |
| No. 9 Black Republican | 857 | 23.6 |
| No. 11 Black Oregon | 500 | 1.8 |
| No. 16 Black Oregon | 878 | 17.8 |
| No. 12 Norma | 713 | 26.9 |
| No. 13 Norma | 603 | 31.6 |
| No. 15 L. S. Waterhouse | 707 | 11.4 |
| No. 10 L. S. Waterhouse | 282 | 4.9 |
| No. 7 Black Tartarian | 530 | 31.3 |
| No. 17 Abundance | 534 | 9.5 |
| Centennial from Idaho | 294 | 9.8 |
| Centennial No. 3 (Milton) | 352 | 11.3 |
| Black Tartarian (Milton) | 256 | 22.2 |
| Check | 753 | 42.1 |
| Bing X | | |
| No. 2 Centennial | 480 | 48.3 |
| No. 3 Centennial | 776 | 50.3 |
| No. 1 Black Republican | 876 | 63.8 |
| No. 4 Black Republican | 839 | 58.0 |
| No. 5 Black Republican | 646 | 30.8 |
| No. 6 Black Republican | 869 | 58.8 |
| No. 9 Black Republican | 1101 | 52.8 |
| No. 11 Black Oregon | 1262 | 2.1 |
| No. 16 Black Oregon | 511 | 48.5 |
| No. 12 Norma | 796 | 30.8 |
| No. 13 Norma | 463 | 52.2 |
| No. 15 L. S. Waterhouse | 485 | 23.0 |
| No. 10 L. S. Waterhouse | 256 | 25.7 |
| No. 7 Black Tartarian | 995 | 44.1 |
| No. 14 Abundance | 1003 | 7.4 |
| No. 17 Abundance | 632 | 51.2 |
| Check | 1118 | 17.8 |
| Lambert X | | |
| No. 2 Centennial | 814 | 46.0 |
| No. 3 Centennial | 972 | 44.7 |
| No. 1 Black Republican | 1562 | 53.2 |
| No. 4 Black Republican | 1006 | 37.2 |
| No. 5 Black Republican | 770 | 64.0 |
| No. 6 Black Republican | 906 | 58.9 |
| No. 9 Black Republican | 940 | 50.0 |
| No. 11 Black Oregon | 823 | 2.7 |
| No. 16 Black Oregon | 1141 | 47.6 |
| No. 12 Norma | 902 | 35.3 |
| No. 13 Norma | 256 | 50.0 |
| No. 15 L. S. Waterhouse | 808 | 33.1 |
| No. 10 L. S. Waterhouse | 798 | 24.1 |
| No. 7 Black Tartarian | 767 | 57.2 |
| No. 14 Abundance | 588 | 20.7 |
| *No. 17 Abundance | 598 | 24.2 |
| Centennial from Idaho | 298 | 51.0 |
| Centennial No. 3 (Milton) | 327 | 52.5 |
| Black Tartarian | 343 | 36.1 |
| Check | 2113 | 40.0 |

*The numbers preceding the varietal name indicate certain trees in different orchards.

**A discussion of a number of varieties used in 1924.** No. 2 Centennial is evidently the true Centennial, and in tests produces an excellent set of fruit. This variety does much better east of the Cascade Mountains than in the Willamette Valley. The single small tree that was available bears very heavily, but will supply only a limited amount of propagating wood. No. 3 Centennial is a large, pointed, soft, white cherry, not of the original Centennial type. It is too soft for commercial purposes.

The Black Republicans are fairly uniform in type, with the possible exception of No. 5, which seems to vary somewhat in tree characteristics, though this may be due to local soils and cultural conditions. The Black Republicans are present in the largest quantity, and are from plantings that have been producing heavily in the past.

No. 16 Black Oregon is a distinct variety, possibly having a value as a shipping cherry, and of value with the Bing and Lambert as a pollenizer. It has a dark color, dark flesh, is medium in firmness, but only available in a relatively small quantity. No. 11 Black Oregon is evidently a variant of the Bing.

Nos. 12 and 13 Norma are the same variety, the one possibly a little better, due to better root stock and general vigor. The Norma is an early red, medium-sized cherry, of value for early local shipment. The tree is smaller than the average sweet cherry, but produces very heavily year after year. As all the trees were originally propagated at one time from a local seedling, there is little variation except in vigor.

No. 15 Long Stemmed Waterhouse is a large-fruited variety, the scion wood having originally come from B. I. Ferguson's place at Salem, Oregon. No. 10 Long Stemmed Waterhouse is of a small-fruited, large-pitted form, several of which are commonly found distributed as the Long Stemmed Waterhouse.

No. 7 Black Tartarian is the usual early maturing type. As a pollinizer it is of doubtful value, due to the earliness of blooming, especially for the Lambert. It will work with the Napoleon and also fairly well with the Bing. As to the fruit, it is of no value for Oregon, as it has to meet the competition of better late varieties from earlier sections.

No. 17 Abundance is a seedling of the Abundance type, yielding heavily of good sized fruit.

The others listed in the tables were not available, due to killing by frost in the late spring.

In the matter of propagating young trees for new orchards, there will be slight shortage of stock for a year or two, but this will quickly right itself. For top-working old orchards, there is an abundant supply of Black Republican, Norma, and Long Stemmed Waterhouse. For The Dalles district the Black Republican is the most popular variety as a shipping cherry, but has less value for the Willamette Valley. The Long Stemmed Waterhouse is being less favorably considered as time goes on, due to the fact that it will not rate as a first class cherry for canning. Being quite similar to the Napoleon, it is easily mixed in picking, but in canning a mixture of the two gives a very poor product, rating second class at best.

The choice of the pollenizer to use is largely a local question, determined in part by the market available. In many cases its value will rest largely in its ability to set fruit on the Napoleon, Bing, or Lambert. The first requisite should be efficiency in cross-pollination.

**Using sour cherries as pollenizers.** Since the sour cherry is found so commonly in the Pacific Northwest in home plantings where the sweet cherry also has been planted, it was thought possible that the sour cherry could be used as a pollenizer. This was of interest, especially in those districts where the sour cherry was being canned commercially with the hope of combining two canning cherries. Results are shown in Table XIII.

TABLE XIII. NAPOLEON CROSS-POLLINATED BY SOUR CHERRIES

| | 1921 | | 1922 | | 1923 | |
|---|---|---|---|---|---|---|
| | No. of flowers | Percent set | No. of flowers | Percent set | No. of flowers | Percent set |
| | | % | | % | | % |
| Napoleon | | | | | | |
| X Dyehouse | 45 | 15.5 | ------ | ------ | ------ | ------ |
| X E. Richmond | 18 | 0 | ------ | ------ | ------ | ------ |
| X E. Richmond | 28 | 3.5 | 634 | 1.1 | 212 | 17.9 |
| X Montmorency (Monarch) | 51 | 5.8 | ------ | ------ | ------ | ------ |
| X Montmorency (Sweet) | 38 | 0 | ------ | ------ | ------ | ------ |
| X Ostheim | 8 | 25.0 | ------ | ------ | ------ | ------ |
| X Timme | 16 | 6.0 | ------ | ------ | ------ | ------ |
| X Montmorency (Large) | ---- | ------ | 401 | 15.2 | 230 | 14.7 |
| X May Duke | ---- | ------ | 547 | 3.1 | 466 | 18.6 |

Sour cherries will set fruit on the sweet cherry, but in comparison with varieties of the sweet cherry are poor pollenizers. The results with the other sweet cherries, Bing and Lambert, are similar to those with the Napoleon. On the whole, while fruit will be set by using sour cherries as pollenizers, their use cannot be recommended.

## DISCUSSION AND APPLICATION OF RESULTS

**Why heavy crops occasionally.** A question that has frequently arisen has been, why in some years there would be a heavy crop in those orchards with a very few pollenizers, while for a period of years intervening there would be a very light crop in the same orchard. During 1922 and 1923 the crops were about average. In 1924 the crop was heavy where it was not affected by the frost. During 1922 and 1923 pollination was performed artificially with flowers that were neither emasculated nor sacked. In other words, these flowers were left open for insect pollination, but received artificial pollination in addition, as a comparison with those that received cross-pollination by insects only. Table XIV records the results.

TABLE XIV. HAND POLLINATION VS. INSECT POLLINATION. FLOWERS NOT EMASCULATED

| | 1922 and 1923 | |
|---|---|---|
| | No. of flowers | Percent set |
| | | % |
| Lambert | | |
| X Governor Wood | 763 | 61.7 |
| X Insect pollination | 2000 | 2.5 |
| Napoleon | | |
| X Black Tartarian | 690 | 76.2 |
| X Governor Wood | 1714 | 80.0 |
| X Elton | 612 | 54.5 |
| X Insect pollination | 1932 | 12.9 |
| Bing | | |
| X Governor Wood | 1082 | 63.0 |
| X Insect pollination | 1445 | 5.9 |

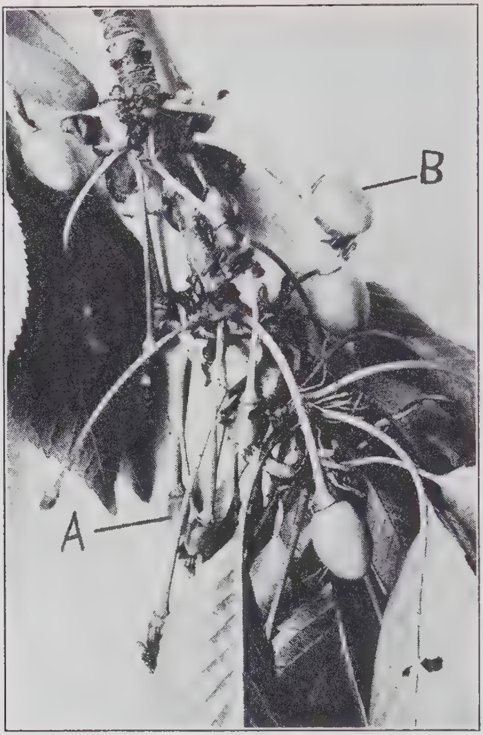

Fig. 3. Fruits partly (A) developed but ready to fall as contrasted with those that are making a normal growth (B). Where proper pollination is not provided the cherries will partly develop and then drop.

TABLE XV. CROSS-POLLINATION BY USE OF LIMBS

| | No. of blossoms | Percent set |
|---|---|---|
| | | % |
| 1923 | | |
| Lambert | | |
| X Norma | 682 | 36.6 |
| X Insect pollination | 430 | 4.8 |
| Napoleon | | |
| X Norma | 641 | 31.6 |
| X Insect pollination | 739 | 2.8 |
| 1924 | | |
| Bing* | | |
| X Black Republican | | |
| Limb No. 1 | 612 | 24.0 |
| Limb No. 2 | 330 | 21.8 |
| Limb No. 3 | 990 | 42.7 |
| Limb No. 4 | 400 | 14.5 |
| Insect pollination | 625 | 10.5 |

---

*To do the cross-pollination a limb twenty inches long with 130 blossoms was used, beginning with limb No. 1 and finishing with limb No. 4.

From the results shown in Table XIV, it can be seen that the cause of the short crop was not lack of ability of the flowers to develop fruit, but apparently was the lack of pollination (Fig. 3). Since where the pollen was placed on the stigma a large percentage of the flowers set fruit (Fig. 4), it was apparently a matter of lack of transfer of pollen.

Table XV shows the same results in 1923 and 1924, where pollination was done in a rough way, merely by taking a limb of the pollenizers and rubbing it over a limb or two of the commercial variety (Fig. 5). The pollen was transferred in this way where the insects failed. These experiments were carried on in orchards where the pollenizing trees were very few in number. Apparently if the pollen was transferred the fruit would set, but why should this occur naturally in orchards only every few years?

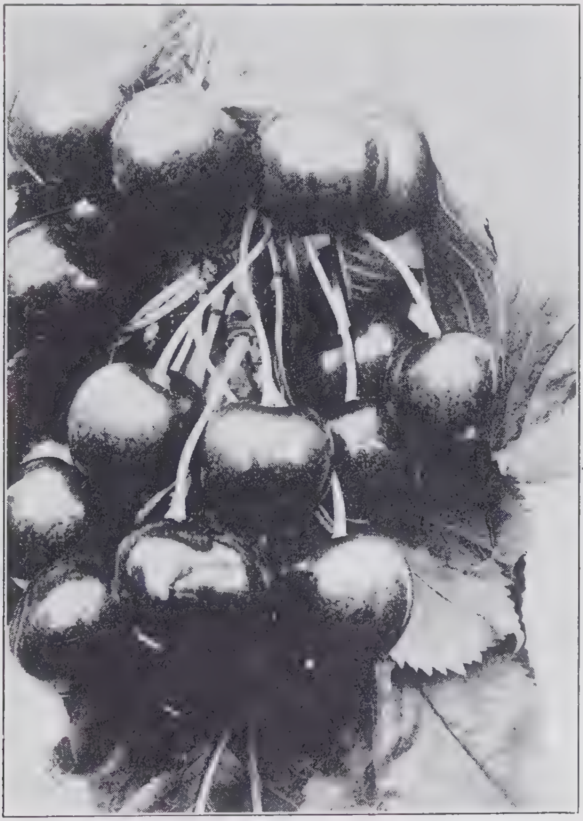

Fig. 4. A cluster of fruit. The flowers had the proper kind of pollen placed on the pistils.

**Temperature and insects.** While working in the orchard in 1922 the temperature was above 64° F. only for very short periods at a time. During these periods insects, including the honey-bee, were numerous in the orchard. As the temperature was lowered, fewer and fewer insects could be noticed. This cool temperature did not allow for the presence of the natural agents of pollen distribution. It was not the lack of ability of the tree to bear fruit, as shown by the experiment, but was the lack of the presence of proper pollen. Going back over a period of years and studying climatic conditions, it is noted that the years of heavy crops coincided with years of high temperatures during the blooming season.

Bees are said to range very little from tree to tree in their quest for honey. In those orchards where pollenizers are plentiful this slight ranging of the bees will distribute a considerable amount of the right kind of pollen, even under cool conditions. Since in warm weather many more trips will be made to the orchard, the chances of distributing the pollen will be that much increased. It might be deduced, therefore, that the warmer the weather in any locality, the less the necessity of a large number of pollenizers, and the cooler the weather, the greater the necessity of an abundant supply of pollenizers. The danger of the occurrence of these cool seasons, however, makes it imperative to prepare for such seasons by providing the number of pollenizers necessary for efficient cross-pollination during the cool seasons as well as during the warmer seasons (Fig. 6).

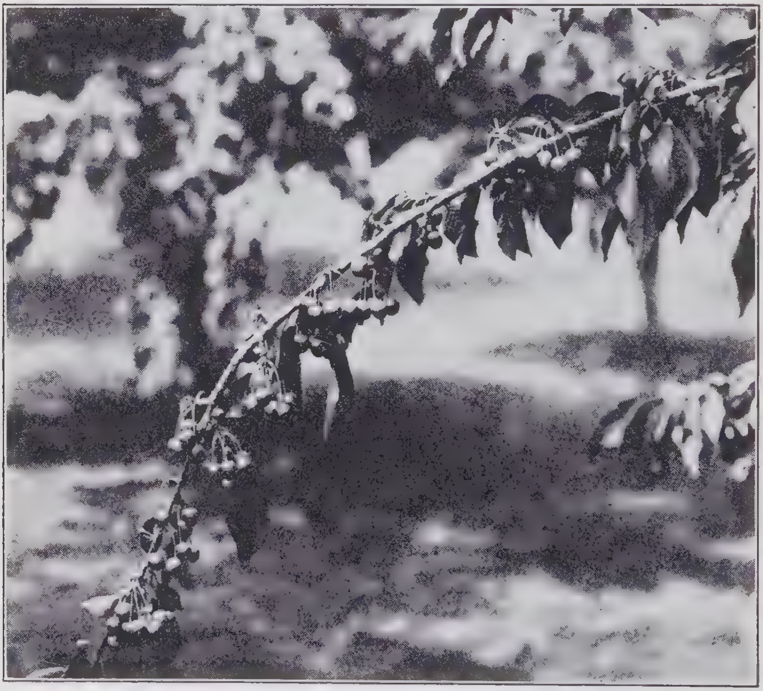

Fig. 5. Fruit set by brushing one limb of the pollenizer over a limb of Napoleon.

**Bees in the orchard.** With fruit so dependent upon cross-pollination as are cherries, the agents responsible for this transfer of pollen need to be considered. The number and presence of wild insects can be controlled very little, but the honey-bee can be controlled to a great extent. It is becoming the practice for cherry growers either to keep their own bees or to hire stands of bees during the blooming season. One hive to one or two acres of cherries is sufficient if the stands of bees are strong.

Bees tend to fly against the wind when leaving the hive so as to fly with the wind when loaded and coming back to the hive. This point should be kept in mind when placing the hives.

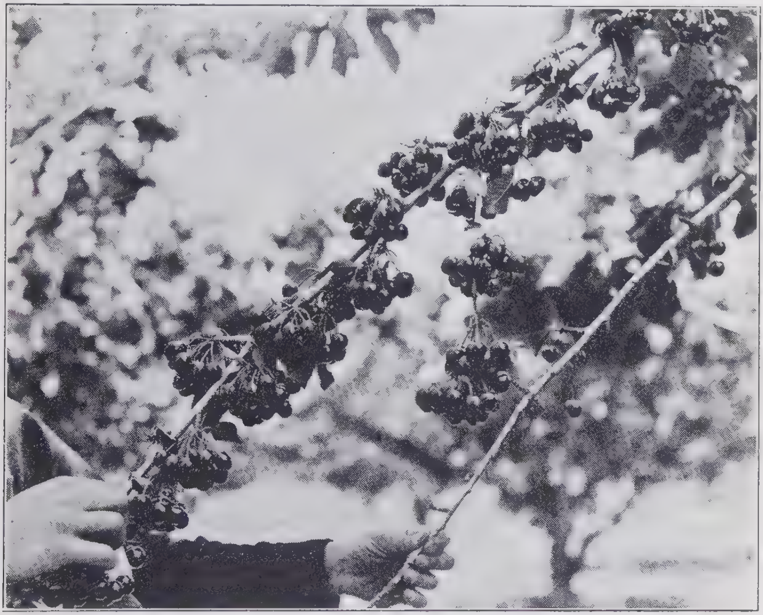

Fig. 6. Hand pollination as contrasted with insect pollination. The season was cool, permitting a limited flight of insects and pollenizers were scarce. The illustration shows that the flowers were capable of setting fruit if the proper kind of pollen was available.

**Placing pollenizers in the field.** As a rule one pollenizer in nine, or every third tree in every third row, is sufficient. With this method of placing, every tree is more or less in direct contact with the pollenizers, although some are at greater distances than others.

Attempts to reduce the proportion of pollenizers to one in sixteen or to one in twenty-five have proved ineffective, as in too many seasons the second tree away does not receive sufficient cross-pollination. In those districts where a cool temperature is apt to occur during the growing season, a greater number is necessary, and by some growers pollenizers have been planted in a greater proportion than one to nine. In cases where the trees are set out in the hexagonal system, some are placing the pollenizer in the center of the hexagon, giving one pollenizer to six of the commercial variety.

*Top-working older trees.* Many old cherry orchards of the state fail to bear, due to the absence of the proper kind of pollenizer, a condition which can be overcome by top-working with some approved pollenizer. In most cases it will be best to graft over the whole tree, but with old trees it is not advisable to do all the work at one time. A better practice would be to graft a third of the tree each year. If the top third was grafted the first season, the next third the second, and so on, there would be little danger of knocking out the young grafts put in the first season. This method of grafting over a period of years will avoid over-stimulation of the wood growth by distributing the stimulation over that time, which practice is more apt to bring about early blooming of the new grafts.

*One limb to a tree.* With some of the largest and oldest trees, it is difficult to graft over a whole tree. This difficulty is being avoided by grafting over one or more limbs to a tree. From a pollenization standpoint this is the ideal method, since a limited ranging of the bees spreads the pollen better where it is in every tree.

Grafting more than one limb to a tree has its disadvantages. The graft must be provided with plenty of room and sunlight. If crowded, the growth will be stunted. A limb should be selected that is out in the open, or the other limbs should be cut away. With the old trees this will usually be some distance from the ground, entailing considerable extra work throughout the season.

Another difficulty with this method comes during picking time. Unless the pollenizing variety is strikingly different from the commercial variety, the fruit of the two will be picked and mixed together in the boxes. With most varieties the mixture must be separated later at a considerable expense. If the pollenizing variety is picked first, this trouble can be avoided, but this requires additional labor and expense. Another way is to graft in a variety that is worthless and no temptation for the pickers. This fruit can be left on the trees and the pollenizing part of the tree considered only for the pollination effect and not from the fruit-producing standpoint. This is probably the better method of the two. If the time comes when a pollenizing variety is found that can be promiscuously mixed with regular varieties, the method of putting one limb to a tree as a pollenizer will be the best way of providing pollination, but as yet it is of doubtful value except for the older trees.

*Grafting over the tree.* When top-working cherry trees for the introduction of pollenizers was first started, all the work was carried on near the ground so as to avoid too high heading of the tree. In doing this, large cuts were made, in many cases up to six inches or more in diameter. The scions started well, but the exposed cut was too large to heal over quickly, and as a result heart rot set in in many cases.

It is now recommended that no cuts be made larger than two to two and one-half inches. This will necessitate many more cuts and a larger number of scions, but it is felt that the added protection against heart rot is worth while.

Due to the fact that the bark of the cherry will peel back very readily from wounds and especially cleft grafts, wrapping the end of the limbs with waxed cloth is of advantage. In some sections hot days are often injurious to young grafts, so that protection by means of paper sacks will aid in giving a better stand. After the work is done, it is often found that the grafting wax will crack so that rewaxing will be necessary.

Suckers will usually start out near the end of the cut and unless these are removed they will soon choke out the graft. Care in all these cases is necessary during the first year of the work.

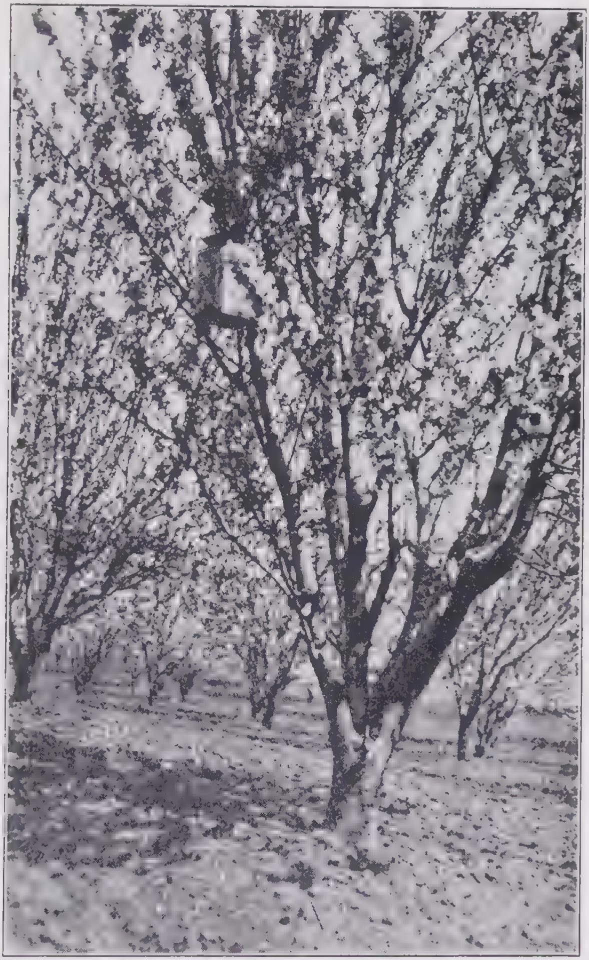

Fig. 7. Placing cans on limbs in the trees. This is practical only with a large supply of the pollenizing material. It can not under ordinary conditions be very efficient but can be used as an aid in obtaining crops.

*Other practices in pollination.* Where the growers are planting Mazzard trees and top-working to avoid gummosis, some are leaving a limb of the Mazzard for pollination purposes. Some of these will be successful and others will not be. Each is an untried individual and will have its individual reaction toward the commercial variety. Where the method is being used, the grower is gambling on enough of the Mazzard trees being good for pollination purposes, and that by leaving one limb to a tree enough effective limbs will be present in the whole orchard to furnish sufficient cross-pollination.

In orchards where it is necessary to graft in pollenizers it is some time before this material will be blooming. As a help in the meantime, limbs of flowers are often placed in the orchard. These are taken from trees known to be effective in cross-pollination and placed in buckets of water throughout the orchard.

Fig. 7 shows how cans can be suspended in the trees and limbs with blossoms placed in them.

The efficiency will depend upon having the right pollenizers and the amount of material available to use. Large amounts scattered through the orchard, with an abundance of insects, will necessarily be the most effective.

*Where and how to obtain grafting wood.* This in part can be obtained from certified blocks at The Dalles, as stated before. The locations of all these trees have been recorded and the records left with the county agent and the secretary of the Chamber of Commerce, The Dalles, Oregon. In many instances throughout the state the Napoleon, Bing, and Lambert have been planted with a single other tree and all the trees are bearing. Where these groups are some distance from other trees, such trees will be the very best source of supply for propagating wood, as it is a proved combination of varieties for cross-pollination. In other instances such combinations are not available, but a grower with a non-producing orchard can find out what material can best be grafted into his orchard. By the method used in Table XV, rubbing a limb of flowers of the kind to be tested as a pollenizer over the flowers of a commercial variety will indicate its value as a pollenizer. It would be best if such flowers of a commercial variety were enclosed in a sack and opened just long enough so that pollination could be completed. The limbs of the pollenizers should be selected just before the blossoms open, and placed in water in a room where insects could not reach them. When the blossoms open out, thoroughly rub the one on the other. This will not give as high a percentage of set of fruit as by careful hand methods, but where the pollenizer is effective there will be a higher set of fruit than is needed for commercial crops and also higher than that produced by natural pollination.

A very little work by the grower will show what material is best and will do away with the possibility of failure. As stated before, there may be different cherries under the names of Bing, Napoleon, or Lambert, and the material certified to as pollenizers by the Experiment Station may not work in all cases. It would be impractical to test all the old orchards in the state to determine the proper pollenizers for each one. While the Napoleon may be true to name in all cases, there is a possibility that it may not be so. If a grower cares to spend a few hours during the blooming season in testing his own trees this possible risk can be averted.

The material certified to by the Experiment Station has been shown by work during one to three years as being correct for the type of Bing, Napoleon, and Lambert found at The Dalles and in a limited way that found on the grounds at Corvallis. Due, however, to the evident confusion in the nomenclature and the lack of ability absolutely to identify any variety at this time, these data may not always apply in all orchards; hence the recommendation for personal tests of the older orchards.

For the nurserymen propagating cherry trees there will soon be an abundant supply of certified wood, or the nurserymen may locate their own supply about which there can be no doubt. The indiscriminate propagation and combining of so-called varieties in the field should be discouraged and only stock from proved sources should be planted.

## PRELIMINARY DATA ON THE SOUR CHERRY*

As the sour cherry is being planted to a certain extent in Oregon, and as a few trees, from observation, were not satisfactory in bearing, preliminary work was begun with this fruit in 1922. Of the varieties tested in 1922, only one showed real promise of being self-fertile, and for that reason the work was followed during the two past seasons. The results of three years' work on the self-sterility of the sour cherry are given in Table XVI. The results indicate the same tendency as found in England and France; namely, that self-sterility or self-fertility depends upon the variety.

TABLE XVI. SELF-STERILITY OF THE SOUR CHERRY

| | 1922 | | 1923 | | 1924 | |
|---|---|---|---|---|---|---|
| | No. of flowers sacked | Percent set | No. of flowers sacked | Percent set | No. of flowers sacked | Percent set |
| | | % | | % | | % |
| Montmorency (Sweet) | ------ | ------ | 500 | 1.0 | 586 | 2.3 |
| Suda | 443 | 16.0 | 500 | .8 | 549 | 12.0 |
| Terry | 462 | 0 | 500 | 0 | 585 | .17 |
| Timme | 488 | .3 | 500 | .6 | 444 | .4 |
| English Morello | 419 | 8.8 | 500 | .4 | 749 | 9.9 |
| Wragg | 263 | 8.7 | 500 | .4 | 509 | 1.5 |
| Baldwin | 56 | 0 | 500 | 0 | 633 | 0 |
| Dyehouse | 880 | 0 | 500 | .6 | 526 | .1 |
| †Early Richmond | 493 | 7.5 | 500 | .2 | 557 | 0 |
| Ostheim | 317 | 0 | 500 | .2 | 671 | .1 |
| Montmorency (Large) | 886 | .5 | 500 | 0 | 587 | 2.0 |
| Montmorency (Monarch) | 529 | 7.7 | ------ | ------ | ------ | ------ |
| †Early Richmond | 608 | 0 | ------ | ------ | ------ | ------ |

Table XVII shows the results of cross-pollination work for two years. Although frost interfered very seriously one season the table shows that in many cases cross-pollination is effective and necessary.

As the Montmorency is the one variety most commonly planted, it would seem wise from a study of these data to interplant with some other variety. Especially is this the case since a large amount of propagating wood has been taken from the orchard in which this work was carried on and in which the Montmorency was shown to be self-sterile. Several types of the Montmorency have been tested and none have yet been found to be self-fertile, but all are among the group that is nearly, or entirely, self-sterile. Work in the future will be carried on to locate, if possible, a Montmorency that does not need cross-pollination.

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*Most of these data are by J. H. Painter from a thesis presented in partial fulfillment of requirements for the Master's degree, June, 1924.

†From different sources.

In most of the plantings made there has been intentionally, or otherwise, an interplanting with other varieties. The Early Richmond, commonly called the Kentish, is one of the varieties most commonly found interplanted with the Montmorency. As such combination invariably gives a good crop, it works very well from a pollination standpoint, although the Kentish is not as good a canning cherry as the Montmorency.

TABLE XVII. CROSS-POLLINATION OF THE SOUR CHERRY

| | 1924 | | 1923 | |
|---|---|---|---|---|
| | No. of flowers | Percent set | No. of flowers | Percent set |
| | | % | | % |
| Montmorency X Montmorency | 475 | 0 | ------ | ------ |
| Montmorency X Early Richmond | 450 | 3.1 | 500 | 8.0 |
| Montmorency X English Morello | 473 | 4.6 | 500 | 16.0 |
| Montmorency X Dyehouse | 505 | 2.4 | ------ | ------ |
| Montmorency X Baldwin | 494 | 1.4 | ------ | ------ |
| Early Richmond X Early Richmond | 455 | 0.6 | 510 | 4.0 |
| Early Richmond X English Morello | 514 | 6.4 | ------ | ------ |
| Early Richmond X Dyehouse | 483 | 7.4 | ------ | ------ |
| Early Richmond X Montmorency | 509 | 5.3 | 500 | 2.0 |
| Early Richmond X Montmorency sweet | 447 | 2.9 | ------ | ------ |
| Early Richmond X Baldwin | 432 | 4.1 | ------ | ------ |
| English Morello X English Morello | 380 | 6.0 | ------ | ------ |
| English Morello X Early Richmond | 334 | 8.6 | ------ | ------ |
| English Morello X Montmorency | 382 | 10.7 | ------ | ------ |
| English Morello X Dyehouse | 423 | 12.0 | ------ | ------ |
| Ostheim X Ostheim | 481 | 0 | ------ | ------ |
| Ostheim X Baldwin | 530 | 0 | ------ | ------ |
| Ostheim X Montmorency sweet | 484 | 0 | ------ | ------ |
| Ostheim X Early Richmond | 462 | 0 | ------ | ------ |

## B. PLANTING AND CARE OF CHERRIES

### DISTRICTS FOR CHERRY GROWING

The state can be roughly divided into two districts, Eastern and Western Oregon, separated by the Cascade Mountains. In the eastern part, as at The Dalles, Milton, Freewater, and Cove, the shipping cherry is of first importance with canning cherries of secondary importance at the present time. In Western Oregon the canning cherry is of greatest importance.

This division is due more to the presence or absence of brown-rot infection and decay from molds, than any other factor. Due to the low humidity of the Eastern section, brown-rot is seldom present in large enough quantities to do damage, so that shipping of fresh fruit is a regular annual business. On the other hand, seasons are comparatively rare west of the mountains that are dry enough to permit of general shipping of cherries. With the high humidity and the general presence of brown-rot and blue mold spores, the shipper of any stone fruit is always confronted with the possibility of rapid decay. For that reason, the canning cherry, which is practically only the Napoleon or Royal Ann, will dominate the cherry industry in Western Oregon. Canning cherries of equal quality are grown east of the mountains, but due to the better prices received lately for the shipping cherries, these latter are receiving increased attention.

Sour cherries are being planted to a certain extent. In small quantities they have been profitable, but it is doubtful if large acreages should be planted. Very large quantities of sour cherries are being produced in the eastern part of the United States as cheaply as in the West. It would seem inadvisable, therefore, to plant such acreage as would give a surplus over local demands. Enough sour cherries for the western canneries to supply the local demand would be sufficient, but a surplus over that amount would mean either a loss from not canning, or an attempt to ship and compete in the eastern markets. With the high freight rates it does not seem probable that this would pay. Sweet cherries on the other hand, being produced almost exclusively on the Coast, have a bigger future.

## VARIETIES

Except for purposes of pollination, plantings of sweet cherry are confined to the Bing, Lambert, and Napoleon.

The Bing and Lambert are the large, dark red cherries with the firm flesh that are so suitable to the shipping trade. Neither is adapted to commercial canning, as they will pit the cans within a short time. Experiments are being carried on to determine methods for canning them commercially, and if successful may result in the canning of quantities of Bings and Lamberts. Canned in glass these varieties have a quality that is unexcelled.

The Napoleon, the leading white cherry, is used both for shipping fresh and for canning, but finds its greatest use in the latter trade.

The secondary varieties have been discussed under the section dealing with pollination. These varieties generally have little value except in a few locations. The use of early cherries is commercially profitable in a limited way only, as they come into competition with the midseason and late cherries of other sections. The shipping and eating quality of these other cherries precludes the use of early cherries in Oregon, except in a local way.

The Montmorency is the best sour cherry for commercial planting. Other varieties planted will be according to pollination demands as indicated previously in this bulletin.

## LOCATING AN ORCHARD

**Guard against frost.** With the relatively early blooming of cherries comes the need for locations that are frost free. In general a slope at some elevation above the surrounding territory is the best insurance against frost (Fig. 8). This slope should be sufficient to afford good water and air drainage without obstructions below, so that a free flow of cold air to lower level can be had.

**Use deep, well-drained soils.** Deep soils are necessary for the cherry's deep-growing root system. Any soil shallower than four feet will be found in time of moisture shortage to be unsatisfactory. While the crop is matured early in the season, the buds are developed after this time, and should have optimum conditions of the tree to insure the best growth. Strong, healthy buds cannot be regularly developed on trees that are suffering from the lack of moisture during the late summer. Weakening of the buds will be felt in the lessened crop the following season.

The shallow soil caused by high water-table or water-logged soil is just as detrimental as one caused by other impervious soil material. Cherry trees grown on water-logged soils seem to be heir to all ills apt to attack the cherry tree. If during the summer the roots are able to penetrate any distance into the soil, the rising water-table of the winter will choke and kill them off, cutting down the root area, which will be unequal to the demands of the top during the next summer.

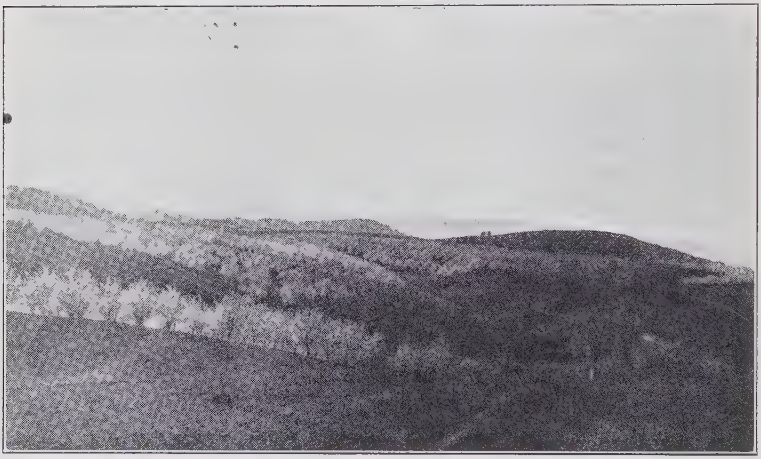

Fig. 8. Orchards placed on slopes will have the maximum protection from frost. Those placed at the foot of slopes or near the bottom will usually suffer first.

## FERTILIZATION PRACTICES

**Provide plenty of food for the tree.** The size of the cherry tree indicates that the tree demands a large amount of plant food or in other words, needs a rich soil. To attain the full size and maximum bearing plenty of opportunity must be provided for the roots to take in a full supply of plant food. Observations of individual old trees of large size provided with plenty of room bear this out in every case.

Young trees on good soil often make a rank growth, and this has frequently led to the belief that cherry trees do not need any fertilization. In most cases the younger trees do not, but as they come into bearing, the development of the tree, with fruit production, proves a heavy drain on the soil fertility and brings about the need of a consistent soil maintenance program. It frequently comes to notice that cherry orchards are very vigorous for the first 12 or 15 years of their life, but when they reach the age at which they should be at their most profitable production, the growth of the tree and the size and quantity of fruit begin to decrease. Alternate bearing is often prevalent. Most of this difficulty can be ascribed to the crowded conditions of a commercial orchard followed by a starvation program. The plant food has been removed for years, and no steps taken to replace it.

With old devitalized trees that show very poor growth, and yellowed leaves, nitrate of soda often gives the quickest response, as nitrogen may be the limiting factor and nitrate of soda has the nitrogen readily available to the tree. It is applied at the rate of 200 to 300 pounds per acre three to four weeks before blooming season. The need of using any commercial fertilizer, however, can only be told by first testing it out in small plots. For this purpose use single or simple fertilizers, as well as combinations of these fertilizers, then leave check plots, or untreated plots, in between, to compare as to the results. These plots need be only a few trees or small parts of an acre. There is no general rule as to the application of fertilizers on cherry trees, as each soil is a problem in itself, depending upon the type of soil and the past cropping treatment it has received. That a certain fertilizer is satisfactory to one grower is no indication that it will be for another, as one soil may have been robbed of one plant food element, while the other soil may have been depleted in another way.

**Cover crops are the cheapest means of fertilizing an orchard.** The use of any commercial fertilizer should be considered as secondary or supplementary to the use of cover crops. At the same time that the plant food is being depleted the ability of the soil to hold moisture is also being decreased. The plowing under of cover crops adds humus to the soil, which increases the moisture-holding capacity of the soil, and at the same time increases the available plant food supply.

The use of vetches with some grain, like rye, oats, or winter barley as a cover crop, is pretty generally practiced. These are planted in equal proportions of twenty to forty pounds each per acre, except a little less of grain, where winter barley is used. Spring vetch is in general use in Western Oregon, while hairy vetch has proved successful in Eastern Oregon. In many cherry orchards it is a problem to start the cover crop in the fall, due to the lack of moisture. Many growers are applying straw, barnyard manure, or any form of straw material, to add fiber to the soil, in order to bring the soil to a point where cover crops can be easily grown. In some cases the application in the fall of nitrate of soda, at the rate of 100 to 150 pounds an acre has been beneficial where enough moisture is present to germinate the grain. Rye alone has proved useful where it was difficult to grow any other grain and impossible to use vetch successfully. Unless vetches have been grown previously, the vetch seed should be inoculated.

In the red hill type of soil of the Willamette Valley attempts to grow cover crops have frequently met with failure for two to three years in succession, but when the crop is once grown it is usually followed with a little better success each year, until good cover crops are grown annually. In districts like The Dalles it is difficult also to grow cover crops, but the same procedure will have to be followed with modifications suitable to that location. Cover cropping is the cheapest and most practical method to use in building up the soil for moisture conservation, and providing large amounts of available plant food.

## PROPAGATION

**Use proved material.** As stated before, indiscriminate propagation of varieties should be superseded by propagation of proved trees and combinations of trees. While any combination may not be equally successful under all conditions, the use of proved material will eliminate much that is known to be unsuited as it is found to be when indiscriminately propagated from any source that has been untried.

**When to use Mazzard rootstock.** In those sections where bacterial gummosis of sweet cherries is serious, and that is principally west of the mountains, the use of the seedling Mazzard tree is to be recommended. Mazzard seedlings show a high degree of immunity to bacterial gummosis. For that reason they have particular value and are planted in the field, where they are allowed to grow for a season or two. Then if the commercial varieties are budded or grafted onto the scaffold branches 6 to 10 inches from the trunk (Fig. 9), a trunk and lower scaffold branches will be had that are nearly immune from attacks by gummosis. The disease may kill individual limbs of the top, but cannot kill the whole tree, as was the case where the trunk was of a commercial variety.

In the districts where bacterial gummosis of sweet cherries is not serious, the practice is not to be recommended, as the extra care and work are expensive. East of the mountains bacterial gummosis is of little importance, so this form of propagation is of no particular value in those sections.

Investigations show that the Mazzard root is more vigorous and able to cope with adverse conditions, such as dry seasons, than is the Mahaleb. This latter root also has a dwarfing effect on the sweet cherry, so that the Mazzard seems to be the best stock to use in the nursery. Some nurserymen of Eastern Oregon are using the Mazzard root, budded to the Lambert, and later top-working to the other varieties, due to the fact that the Lambert is fairly hardy to winter conditions. This double working is not generally in use as yet.

## PLANTING AN ORCHARD

**Time of planting.** The trees in the districts west of the mountains should be obtained as early as possible from the nursery after they are dormant, and then planted out the first time the soil is fit for planting. Early planting allows the trees to develop a good root system, for under the Western Oregon conditions the roots are growing and developing throughout the winter. This will allow the formation of a good root system that can furnish plenty of moisture and plant food when the tree is demanding it most during the summer.

Under Eastern Oregon conditions the above directions will not apply so well, and early spring planting may be more advisable, due to severe winter conditions often met with that are more or less serious at times to the younger trees. In either place, late spring planting is to be avoided unless irrigation is used, when the objection to late planting is not so serious, as moisture is available at all times throughout the season.

**Avoid crowding the trees.** As a cherry tree will attain a large size, plenty of distance should be allowed between trees. The earlier plantings in this state were made at distances of 20 to 25 feet, but experience since then has shown this distance to be inadequate. At present the average distance for sweet cherries is about 35 feet between the trees, running from 30 to 40 feet. In the long run nothing will be gained by crowding the trees. Sour cherries are planted 25 to 30 feet apart.

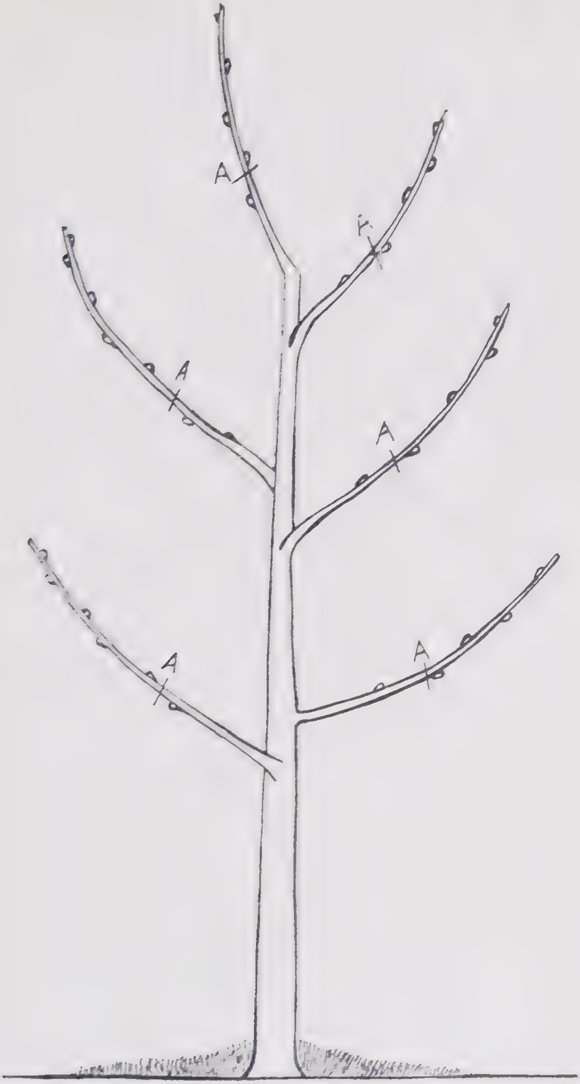

Fig. 6. Budding over a Mazzard seedling. A—points where the buds are to be set.

**Laying out an orchard.** Orchards can be laid out on the square or hexagonal system. The first step is to lay out base lines, with two or more base lines for the square system and one with the hexagonal system.

*For the square system* take one side of the field from which a line can be laid off parallel to the fence or road, such as the base line AB (Fig. 10). With a tape or other measure lay out 60 feet on this line AB. Then on the line AC approximately at right angles to base line AB, lay off 80 feet, striking an arc and using A as a pivot point. From point B with a line 100 feet long strike another arc. Where the arc of AD and BD intersect will be the point through which the line AC may be located permanently and at right rangles to the base line AB.

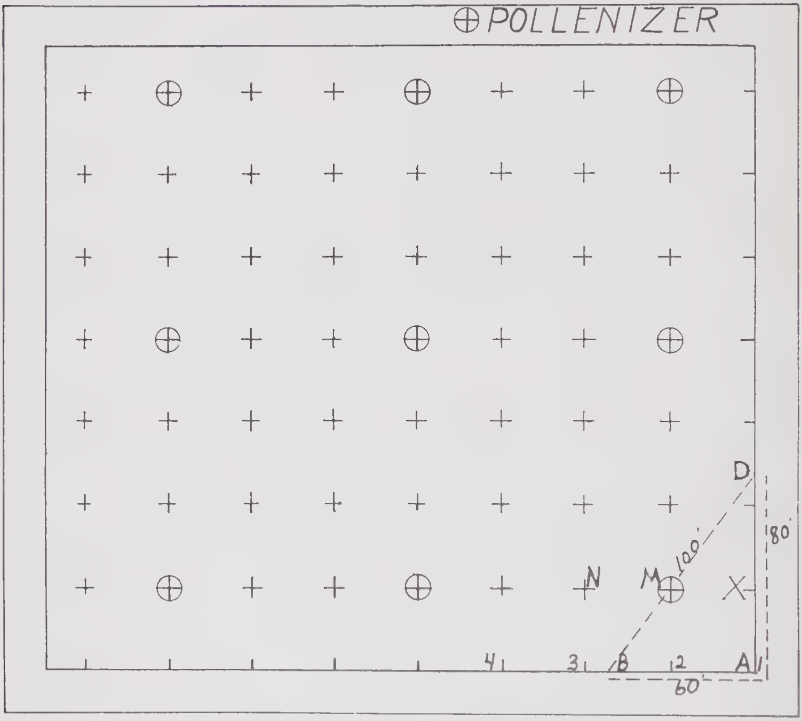

Fig. 10. Laying out a field by the square system indicating the places for the pollenizers.

It is generally of advantage to lay off another base line at the opposite point of the field from A on the base line AB.

As equipment in laying off by the square system, or by the hexagonal system, a set of wires should be provided of the same length as the distance apart that the trees will be set out. These are two wires with one end joined together in a small ring and the free ends fastened to separate rings. After staking off the base line at the intervals desired for the tree, staking of the tract can commence. By placing the wire over stake 2 and take stake X, and drawing it taut, a stake can then be placed at point M. Then move the wires over so that the ring can be placed over stake M and stake 3; a stake can then be placed at the center ring at point N. This process can be carried on indefinitely, backward and forward across the field until the field is completely staked out. The wires should be held in the same plane and drawn up to the same degree of tautness. Occasional checking by sighting or by remeasuring the wires will be necessary to straighten out the rows, especially if the field is uneven.

A long wire with soldered points on it indicating the points at which stakes are to be set is often used.

Other methods of staking out can be used, such as the use of transit or by sighting from two sides of the field with a man to set the stakes at the points desired. On the whole it will probably be found that the use of wire is the quickest and simplest method that can be employed for land not too uneven.

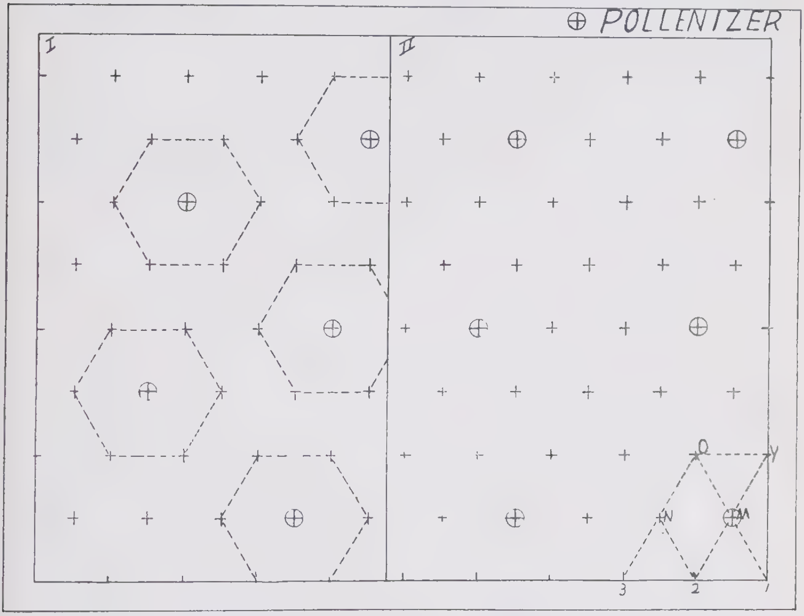

Fig. 11. Laying out a field by the hexagonal or triangular method. I. Pollenizers placed in the center of the hexagon. II. Pollenizers placed every third tree in every third row.

*For the triangular or hexagonal system* one base line only is needed, spaced at the regular intervals for the planting of the trees. Placing the rings over stakes 1 and 2 (Fig. 11), the wires are drawn tight and a stake is set at M. Then move over until the rings are over stakes 2 and 3; the stake is then placed at N and so on throughout the field. In using this method the rows will each time become shorter so that it will be necessary to fill out the side of the field. By placing one free ring over M in the second row and O in the third row, as illustrated, a stake can be placed at Y so that the third row will be lengthened out to the normal length.

**Locate the pollenizers carefully.** After the orchard is staked out, or while being staked, carefully locate the place where the pollenizers will be. In either system, the square or hexagonal, start at M (Figs. 10 and 11), and mark every third tree in every third row. This will place every tree in more or less direct contact with the pollenizers, no one tree being blanketed or covered by trees directly between it and one of the pollenizing trees. With the hexagonal system, two trees out of every nine will be at a greater distance from the pollenizing tree than will any where the square system is used with trees planted the same distances apart as in the hexagonal system. The distance, however, will not be far enough to be serious.

**Keep the trees in line.** To hold the trees lined up so as to give an attractive appearance to the planting, the planting board is of value. This is a board three to four feet long, with a notch cut in at each end and one at the center. The tips of the notch in the center and of those at the end should be in line to insure accuracy. Before digging the hole, place the board so that the center notch is against the stake where the tree is to be set. Then place a stake temporarily at each end of the board, when the center stake and board can be removed. After the hole has been dug and when ready to set the tree, place the board in contact with the two temporary stakes. With the tree held against the center notch, the alignment of the planting can be maintained.

**Protect the roots while planting.** In transferring the trees to the field, protect the roots against drying out. They can be covered with wet burlap or similar material, or placed in a barrel of water. Exposure to air for a short time will materially damage the smaller roots. Do not dig the hole or distribute the trees too far ahead of the time of planting.

Before setting the trees trim the roots. Roots six to eight inches long are long enough for all practical purposes. When broken or ragged ends are found, recut the roots in order to give a smooth surface that will heal over easily.

Set the trees one to two inches deeper than they grew in the nursery. Sift in fine earth around the roots so that there will be no air pockets to dry out the roots. After working the earth well around the roots and putting a layer on top of the roots, tramp it to compact it well around the roots. Finally, finish filling the hole with loose earth. This method, while placing the earth firmly around the roots, tops off with loose earth, preventing rapid evaporation of moisture from the soil.

## PRUNING

**Balance top and roots.** When the trees are transplanted the greater part of the root systems are left in the nursery bed. It is essential, therefore, that a balance be restored between top and roots. This is done by cutting back the top in proportion to the size of the root system when planted. This is the greatest function connected with heading back at the time of setting out. Trees are seldom if ever cut back too severely, but are more often injured by failure of the grower to cut back the tops.

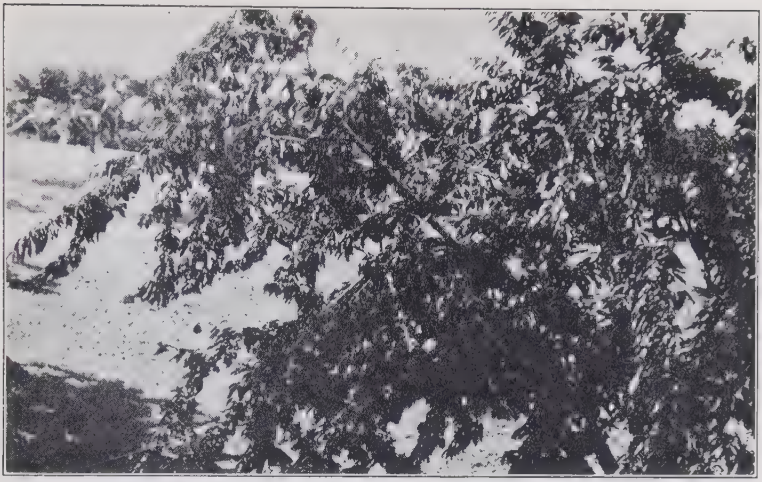

Fig. 12. Fruit on the outside branches pulling the main limb out and down.

In case of this neglect, the evaporation of moisture and other leaf activities are too heavy for the diminished root system during the summer time when the heavy demand is on, so that the tree suffers.

**Build the tree for heavy crops.** The actual height of head or the point at which the tree is cut off will usually vary from 18 to 30 inches.

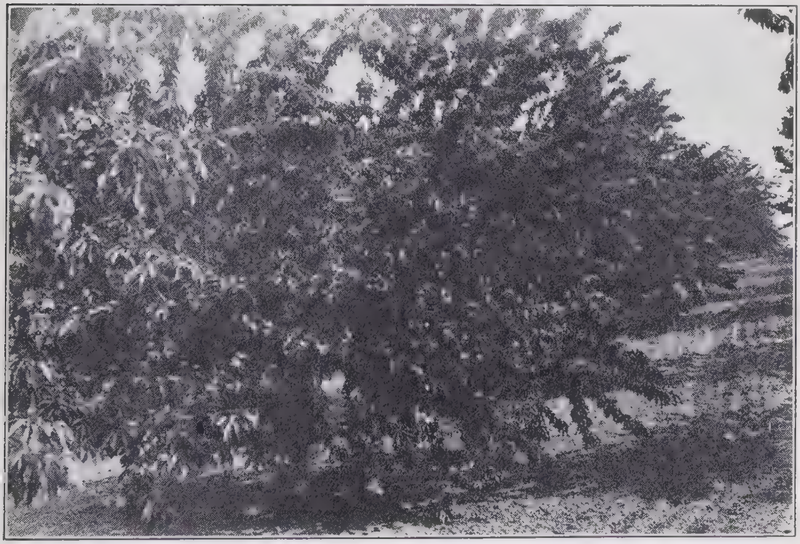

Fig. 13. Trees bending down from loads of fruit. This, with judicious pruning, is the best method of keeping trees low.

The ultimate height of head of a mature tree depends very little on the height of cutting at the time of planting, but rather on the practices followed in later pruning.

After the first season's growth, the scaffold limbs and temporary leaders can be selected. Space the scaffold branches at least 8 inches apart. If only one is produced besides the leader the first year, develop more on the new leader the second year, having from 3 to 6, preferably 5 or 6, when all are placed.

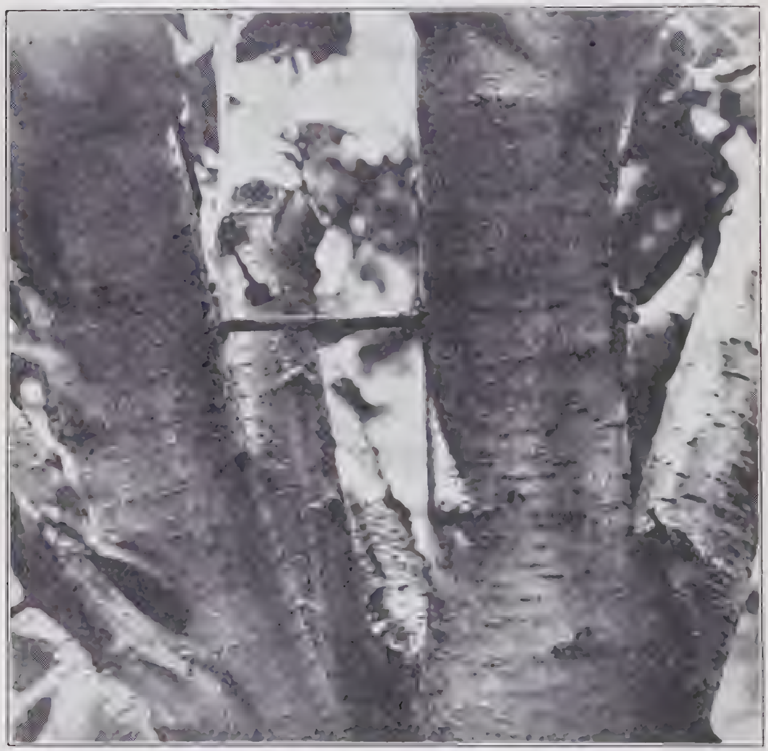

Fig. 14. Method of bracing trees.

At the end of the first year head back the scaffold limbs, as the cherry usually makes such a long growth that if it is left to grow naturally the branching would be too high from the ground and too far apart. This heading should not be closer than 18 inches as provision must be made for a large tree ultimately. If less growth is made than this the first year, wait until the next year before locating the secondary scaffold branches. The spacing after the first year should be farther apart to provide for more room. This later pruning of both young and bearing trees is treated in detail in Oregon Agricultural College Extension Bulletin 368.

**Keep the trees down by heavy cropping.** By pruning or thinning so as to leave the secondary branches on the outside of the scaffold branches the weight of the fruit will open the tree and at the same time lower the height of the head. Providing plenty of pollination to bring about early heavy bearing is the best way of keeping a tree low (Fig. 12). Heading back at intervals, or regularly, defeats the purpose, as the scaffold branches become proportionately thicker in relation to their length and cannot be bent down. The long length developed by thinning out in the long pruning system will bend toward the ground and automatically open and lower the head of the tree (Fig. 13).

**Bracing the tree.** Many of the trees in the orchards now coming into bearing were developed and pruned on the open center system. This system causes the formation of bad crotches by placing the limbs nearly all at one point instead of distributing them over the leader, and permits much breakage or spreading out of limbs unless the trees are well braced. Fig. 14 shows a cheap method of bracing trees. The material is one-half-inch iron rod. After being driven through the holes bored into the limbs, the ends of the rod are bent over an axe or hatchet blade held up against the rod on the outside of the limbs. The tree will soon overgrow the ends of the rod and will form a permanent brace.

## CULTIVATION

**Begin early.** As the cherry blooms early, the cultivation of the soil should begin still earlier, in order to warm up the soil for the roots. When cover crops are being grown, the temptation is to leave them late until more growth is obtained. This may bring about trouble in various ways: first, the grain may become so woody that it will require an excessive amount of moisture to decompose it, drawing moisture from the soil at the time the tree demands it most; second, leaving the cover crop late may result in the cover crop itself using considerable moisture for its own growth, and thus drying out the soil even before being plowed under. If rains cease early in the spring, this is quite a factor. It is practically impossible to get the maximum results in the growth of the cover crop and at the same time maintain the moisture properly in the soil. On the whole, it will be necessary, especially at first, to sacrifice the cover crop to a certain extent in favor of moisture retention, by the practice of plowing early. After the cover crops have been used for a few years, and the physical condition of the soil is improved, it will be possible to delay plowing somewhat, though the advantage of warming up the soil early should not be lost sight of.

**Cherries respond to good cultivation.** It seems to be the fact that a cherry tree grown in deep soil, once established, grows and bears after a fashion with the minimum of care. This has led to the theory that cherries should not be plowed or cultivated. While the individual tree, under special conditions, may do fairly well, the commercial orchard should have the same cultivation as would other orchards, beginning with the early plowing in the spring, and following with such forms of cultivation as will put the soil in good tilth. Cultivation should be carried on throughout the season. Even after the crop is picked, cultivation will be advisable, in order to give good conditions for the development of strong, healthy buds.

**Young trees may grow too late in the fall.** Due to the rank growth of young trees, late cultivation of a new planting is usually not necessary or advisable. If the trees are forced to grow late in the season, they will be susceptible to winter injury, due to the fact that the tissues have not properly hardened down before cold weather comes. Cessation of cultivation early in the season, usually during July, will tend to slow down the growth early, thus allowing the trees to harden down the tissues for the winter, preventing winter injury, especially during sudden cold spells.

## HARVESTING

Very few exact data have been available on the proper time of picking cherries. In Circular 61 of this Station (May, 1925) will be found data as to the picking time. On the whole, for best quality, cherries have been picked too green.

The one big factor in shipping fresh cherries has been handling, which includes picking, packing, and cooling, and these operations must be considered in improving the possibility of shipping cherries. Rough handling so as to bruise the fruit does not allow of satisfactory shipping. The fruit should be picked and carefully placed into the picking receptacle. Rough handling often occurs in emptying the fruit into lug boxes. Picking by the pound is responsible for much damage, and it will need close supervision by the growers to reduce the damage to a minimum. Wagons provided with springs are essential. Hauling the fruit several miles on the average roads, and in wagons without springs, is certain to bruise the fruit.

Prompt cooling and keeping cool until delivery to the Eastern markets will prolong the life of the fruit. The fruit is a living organism, going through a regular life cycle. Exposing to warm temperature will hasten these activities, thus shortening the life of the fruit.

## ACKNOWLEDGMENT

The writer wishes to express his appreciation to the following men who allowed the use of their orchards to carry on the work at The Dalles: Dr. G. C. Sanders, R. H. Weber, W. Collins, Messrs. Anderson, Doak and Brackett. Also, to the large number cooperating in furnishing different varieties of pollen for the test. County Agent C. W. Daigh and Secretary W. S. Nelson of the Chamber of Commerce rendered valuable aid at all times. Prof. W. S. Brown has been of service in giving suggestions during the progress of the work.

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*Insects and Diseases.* The most important insects and diseases with their control are fully treated in O. A. C. Experiment Station Circulars 35 and 53, and in a mimeograph on cherry gummosis. These are free on application.

Station Bulletin 213 June, 1925

## Oregon Agricultural College

## Experiment Station

# Common Vetch

By

H. A. SCHOTH

and

G. R. HYSLOP

1885

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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# SUMMARY

1. Vetch is the most important annual legume grown in Oregon. There is annually produced from 15,000 to 45,000 acres.

2. Vetch is used for hay, seed, soiling, pasture, silage, green manure, cover crops, and honey production.

3. Imported Common vetch seed consisting of many varieties is not so good as the more uniform home-grown seed.

4. Vetch is suited to a moist, cool climate free from extremes of heat or cold during the growing season. Western Oregon is the leading producer. Spring planting unless very early is not successful.

5. Medium to heavy, well drained soils are best. Soils very poor in fertility are not productive. Excessively rich soils cause too rank growth and lodging. Common vetch will not stand quite as wet or sour conditions as Hungarian vetch.

6. Inoculation is not commonly necessary for vetch in Western Oregon except on the more acid coast soils.

7. Early planting in the fall (late September to mid October) is best. It may well be earlier for cover and green manure crops. Only very early planting in the spring will make a good growth.

8. Depending in part on seed prices, 60 to 80 pounds alone, or 60 to 80 pounds with 40 pounds of Gray winter oats are the best acre rates of sowing. The 80-pound rate is best when the seed is cheap.

9. Mixtures of grain and vetch are usually preferred for hay and sometimes for seed. Rye-and-vetch is a soiling, cover, and green manure mixture and the seed can be separated fairly well. Oats and vetch are used generally and separation of seed is fairly easy. Barley and vetch, and wheat and vetch, used respectively for silage and hay, are inseparable under ordinary circumstances and should not be sown together for seed.

10. Vetch for hay is ready to cut when the lower pods are about two-thirds filled or when the cereal planted with it is in a soft dough. For silage vetch is cut when the lower pods are two-thirds filled to filled but before the seeds get hard.

11. Seed harvest must be timely to prevent shattering. Handling carefully and careful threshing are essential to prevent loss of valuable seed by shattering and cracking.

12. Good vetch straw is valuable for feed and fertilizer.

13. Vetch seed is sometimes used for feed. It is rich enough in food value but so poor in palatability as to be of small consequence for stock feed.

14. Vetch may be used for early pasture and for hay or seed later. The vetch recovers best in cool moist years.

15. Vetch is highly productive as a silage crop. It is one of the best considering food value and cost of production. The silage is available in summer when pasture is short.

16. Vetch is a good green feed crop for spring and early summer use

17. Vetch is one of the best green manure and cover crops.

18. Vetch should be grown in a rotation, preferably with a cultivated crop like corn or potatoes and a cereal. Vetch grown continuously results in more weeds and there is a disease hazard.

19. Light land-plaster applications have helped vetch yields slightly in the experiments and paid for a short time. On some soils large increases are secured. Lime applications did not pay on this trial although on some very acid soils good results are secured.

20. There are few pests and diseases that are serious with vetch. Rotation and clean farming, to prevent harboring places for insects, animals and diseases, are the best control measures.

21. There are several promising strains of Common vetch for specia uses.

# Common Vetch

By

H. A. SCHOTH

and

G. R. HYSLOP

Common vetch is the most important annual leguminous forage crop grown in Oregon. Botanically it is known as *Vicia sativa*. It is a spring vetch. In Oregon it is commonly called gray, black, or English vetch; sometimes it is called tares.

In this bulletin it will henceforth be referred to simply as "vetch."

It is principally grown in Western Oregon, Western Washington, and California. In these localities of mild winter temperatures it is usually seeded in the fall. It may also be fall seeded in the southeastern states. In these same sections small acreages are often seeded in the spring, but results are usually not as good as when fall seeded.

Because of the importance of this vetch as a general farm crop, the Oregon Experiment Station, in cooperation with the Office of Forage Crop Investigations, Bureau of Plant Industry, United States Department of Agriculture, has done extensive investigational work with it.

The acreage of this vetch in Oregon varies from 15,000 to 45,000 a year. Of this 65 to 75 percent is in the Willamette Valley. There is probably a larger annual percentage of fluctuation in acreage of vetch than for other crops. This is because it is often used as a substitute crop in common rotation systems and because of fluctuations in market prices to which it is subject. Following years of serious insect damage there is usually a reduced acreage. A small acreage of other legumes, especially clover, means a larger planting of vetch, and vice versa. A previous year's surplus of other legume hay usually reduces the current year's vetch acreage. A good fall for seeding results in a larger acreage, while a short season of fall planting reduces it.

Vetch is important in Western Oregon agriculture. It is comparatively easy to grow, is an excellent producer, and can readily be included in Western Oregon cropping systems.

**Vetch has many uses.** Vetch is generally grown as a hay or seed crop, and is also used for soiling, pasture, silage, green manure, cover crop, and honey production purposes. It is a practical annual farm legume.

The value of vetch in this state as a hay crop amounts to from $400,000 to $500,000 a year, and its value as a seed crop is shown by the census to be in round numbers, $125,000 to $153,000 a year. The large number of other uses to which it is put will approximate a value of $50,000 to $75,000 a year. For hay it equals in production per acre either

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**Note:** Forage crop work at the Oregon Experiment Station is conducted in cooperation with the Office of Forage Crop Investigations, Bureau of Plant Industry, United Department of Agriculture, and credit for the results obtained is hereby acknowledged as jointly due to the above named office and the Oregon Experiment Station.

The experimental work reported in this publication was begun in 1914 under the supervision of Professor H. D. Scudder of the Oregon Experiment Station, and carried out during that year by H. M. Carnes. Since that time the work has been continued by H. A. Schoth.

alsike or red clover, and when properly cured is equal to either in palatability and nutritive value.

In the cropping system vetch compares very favorably with other annual and biennial legumes as a soil enricher.

Our vetch seed often comes in direct competition with seed imported from Europe as spring vetch. The annual imports have ranged from 29,900 pounds to 2,075,644 pounds, with an average of 718,300 pounds for the thirteen years beginning with 1911. In the war years 1915 to 1918 imports were at a minimum. While this imported seed and our vetch seed belong to the same species *(Vicia sativa)* they are varietally different. In fact, the imported seed has represented many varieties, a number of which are inferior for use in this region on account of lack of winter hardiness. Oregon-grown vetch seed, which is one of the most winter hardy of the common vetch strains and which has been acclimated by years of growing in this region, is recommended for local use.

**Climatic adaptation.** Common vetch will stand any ordinary climatic conditions likely to be experienced in Western Oregon. The lowest temperature recorded at this Station during the vetch growing season was –14° F., but as there was heavy snow cover, no soil freezing took place, and there was no damage to the vetch. Without snow cover, it is likely that zero temperature and, under some conditions, even higher temperatures would result in winter killing. Where winter temperatures are commonly as low as 10° to 12° F. without snow protection, it is doubtful if vetch will prove profitable.

In the winter of 1924-25, with but little snow cover, a temperature of –8° F. resulted in considerable winter killing of vetch in several districts of Western Oregon.

The vetch showed more winter resistance than Gray oats or Foisy and Rink wheat and O. A. C. No. 7 Winter barley.

Extreme fluctuations in temperature and continued freezing and thawing are usually detrimental to the growth of the plants.

For the most successful production of vetch, a mean monthly minimum temperature of from 32° to 40 ° F. and a mean maximum monthly temperature of from 45° to 75° F. during the growing season, with an annual rainfall of thirty inches or more, quite evenly distributed throughout the fall, winter, and spring months is most desirable.

Table I shows the varying climatic conditions under which the experimental data in this bulletin were obtained.

TABLE I. SHOWING PRECIPITATION AND TEMPERATURE CONDITIONS AT CORVALLIS, OREGON, FOR YEARS 1914 TO 1924 INCLUSIVE

| *Year | Total rainfall | Temperatures in Degrees F. | | Days below 32° F. |
|---|---|---|---|---|
| | | Minimum | Maximum | |
| 1914-15 | 30.60 | 13 - Dec. 21 | 97 - Aug. 28 | 38 |
| 1915-16 | 52.40 | 14 - Jan. 23 | 99 - Aug. 25 | 53 |
| 1916-17 | 33.96 | 8 - Jan. 19 | 103 - July 14 | 61 |
| 1917-18 | 41.67 | 21 - Jan. 31 | 99 - Aug. 25 | 34 |
| 1918-19 | 46.49 | 17 - Jan. 14 | 101 - Aug. 18 | 50 |
| 1919-20 | 32.62 | –14 - Dec. 10 | 101 - Aug. 20 | 81 |
| 1920-21 | 41.25 | 24 - Nov. 11 | 95 - Aug. 7 | 34 |
| 1921-22 | 37.50 | 14 | 100 | 86 |
| 1922-23 | 41.64 | 16 | 96 | 76 |
| 1923-24 | 30.39 | 10 | 100 | 49 |

*Years represented as crop years from October 1 to September 30, inclusive. Data from Oregon Experiment Station Weather Records.

Vetch is a thrifty grower and requires abundant moisture during its growing season. Good early fall moisture gives the seedlings a good start, they go into the winter in a vigorous, healthy condition, and are better able to withstand more extreme climatic conditions. During the late spring, growth is very rapid and much moisture is needed to make maximum forage crops.

Vetch is not a dry land crop, and in sections where the rainfall is under twenty inches annually, its production is impracticable.

**Soil requirements.** Vetch usually grows best on the medium to slightly heavy soil types of good drainage. Most of the reasonably good and fairly well drained lands in Western Oregon that may be farmed in good season, and that are kept free from surface water will produce vetch crops successfully. The better the condition of the land as to fertility and drainage, the larger will be the amount of crop produced.

Excellent crops of vetch are being produced on some of the red hill lands, and on the sandy, silty, and clay loams. The white lands and even some of the black, sticky types, when given adequate drainage, also produce good crops. Surface drainage often suffices, but doubtless underdrainage is preferable.

Drainage is essential to successful production of Oregon vetch. It does not grow successfully on wet land. Lands so poorly drained as to be saturated or have water standing at or on the surface so that the rooting systems are submerged for from one to four months in the year are of no value for the successful production of this vetch.

**Preparation of seed-bed.** The two general methods of seed-bed preparation for Oregon vetch are: (1) plowing and preparing a seed-bed by the usual cultural methods; and (2) "disking in." Each system has its special adaptations determining its use.

(1) Plowing for vetch is usually done on land that has been in winter grain, fall-seeded forage crops, pasture lands, or sod, or is otherwise hard or weedy. Early fall plowing is always preferable. Where time, power, and machinery permit, dry or summer plowing is very often advisable. It makes possible the preparation of the seed-bed soon after the early fall rains and allows earlier seeding, which in general has been found to be profitable. Where it is not advisable to dry plow, the land should be put into seed-bed condition as early in the fall as possible, after the first fall rains.

**Disking cheaper.** (2) Disking for vetch is usually practiced where the land has been fallow, or has been spring plowed and has produced a cultivated crop, such as corn, beans, or potatoes, or has been in spring grain. The land under these conditions is usually free from weeds and is in comparatively good condition. A thorough disking will then fit it for a vetch crop. In some cases the seed is drilled in without previous disking. The advantage of this system is that, since one plowing does for two crops, a large amount of labor is saved. The land can be prepared and the seeding done early in the fall so that the seedlings have a better opportunity for large fall growth. Some growers believe that the firmer seed-bed and the stubble bring vetch through the winter in better condition.

Very often after disking the land it is advisable to harrow, especially where the land has been cultivated, as this levels the land somewhat and makes the seed-bed more uniform. Cross-harrowing is generally best.

Occasionally land that during the preceding season has produced a fall sown grain crop is disked and seeded to vetch. This is usually a poor practice. Under ordinary conditions the land is hard—often weedy, and it is very difficult to get a good seed-bed. This practice can occasionally be followed successfully on mellow soils reasonably free from weed trouble.

A "disked in" practice sometimes followed on land that has been cultivated or in spring grain is to seed the vetch broadcast before disking and disk the seed in. On land in good tilth and free from weeds this practice is usually successful, especially if done early in the fall.

Where vetch is to be used as a green manure and cover crop in orchards that have been well cultivated during the summer, no further soil preparation is necessary before sowing the crop.

**Inoculation.** For best results with vetch the plants must be inoculated. They must have the nodules caused by nitrogen-fixing bacteria on the roots. Most of the lands in Oregon suited to the production of vetch, except in some of the Coast sections, contain the necessary bacteria and do not require artificial inoculation. In the newly developed farm areas, the soil may not contain the necessary bacteria, and in such cases it is best to inoculate. This can be done through the use of pure cultures, by scattering inoculated soil from fields which have previously grown a crop of inoculated vetches or by mixing such soil with the seed before planting. (Pure cultures are obtainable from the Oregon Experiment Station). Obtaining soil for this artificial inoculation is comparatively easy in districts where vetch is commonly grown. If sown broadcast over the field at least five hundred pounds of soil an acre should be used. This soil should be harrowed in promptly and not exposed to excessive sunlight. It appears that the inoculation with soil is most sure of success, but its cost is usually greater than that of pure culture. In the Coast section it is by far the better method.

**Time of seeding.** Approximately 95 percent of the seedings of vetch are made in the fall. Spring seeding is only resorted to during years or on soils when fall seeding is not possible.

Because of the moisture and possibly plant food required for the maximum development of this crop, fall seeding, which utilizes winter and early spring moisture, is always preferable. Vetches planted in the spring are at a disadvantage because they are not sufficiently advanced to utilize the abundant moisture of the early spring. During their late growth they usually suffer for moisture.

Planting should be done as early in the fall as possible. This will be as soon as a good seed-bed can be prepared after the first fall rains. It may vary from September 15 to November 1, and even as late as December 15. Seedings made early in October are usually best, and from November 1 to 15 have often proved successful. Late sowings are dangerous except where the soil conditions are favorable, uniform seeding possible, and winter weather mild.

Table II shows the hay and seed yields of vetch when seedings were made at various dates during fall and spring. The yields of hay in tons of dry matter show a decrease as the fall dates of seeding advance toward December 1. In seed production, the yields also decrease as the dates of seeding advance toward December 1.

TABLE II. YIELDS OF VETCH HAY AND SEED FROM SEEDINGS MADE AT DIFFERENT DATES IN FALL AND SPRING

| Harvest year | Seeding date | Hay yields |  | Seed yields an acre |
|---|---|---|---|---|
|  |  | Tons an acre field dry | Tons an acre dry matter |  |
|  |  | *tons* | *tons* | *bu.* |
| 1914 | Apr. 26 | 0.00 | 0.00 | 0.00 |
|  | Oct. 15 | 3.48 | 2.54 | 20.17 |
| 1915 | Nov. 3 | 4.34 | 3.28 | 27.16 |
| 1916 | Feb. 22 | 3.11 | 2.30 | 28.16 |
|  | Mar. 18 | 3.07 | 2.32 | 23.99 |
|  | Apr. 4 | 1.65 | 1.24 | 12.41 |
|  | Apr. 16 | 0.00 | 0.00 | 0.00 |
|  | Nov. 10 | 3.13 | 2.23 | 16.08 |
|  | Nov. 30 | 2.97 | 2.10 | 18.16 |
| 1917 | Feb. 11 | 3.81 | 2.67 | 17.00 |
|  | Apr. 6 | .50 | .35 | 3.66 |
|  | Oct. 3 | 1.74 | 1.24 | 0.00 |
| 1918 | Feb. 14 | 0.00 | 0.00 | 0.00 |
|  | Apr. 4 | 0.00 | 0.00 | 0.00 |
|  | Oct. 29 | 4.37 | 3.20 | 29.66 |
| Averages: |  |  |  |  |
| Early spring seedings |  | 2.49 | 1.81 | 17.28 |
| Late spring seedings |  | .43 | .31 | 3.21 |
| Fall seedings |  | 3.33 | 2.43 | 18.70 |

The early spring seedings, especially those made in February, were successful except during 1918, when aphis destroyed the crop. A seeding made in March, 1916, was good, but it will be recalled that there was good summer rainfall that year.

Early spring seedings produced successful crops, although not as large as fall seedings.

Late spring seedings in general were failures. The crops produced were very small. Generally speaking, seedings of vetch made after March 10 will not produce worth-while crops at Corvallis. In the lower Willamette Valley and Coast counties having a larger amount of late spring rainfall, slightly later seedings may be made.

Vetch does not make good growth during warm, dry weather. Aphids often damage spring seeded vetch.

**Rates of seeding.** Vetch was sown in these trials at the rate of 40, 60, 80, and 100 pounds an acre alone, and with 40 pounds an acre of Gray Winter oats.

Rate of seeding trials of vetch sown alone varied from 40 to 100 pounds per acre. All of the rate seedings were made in the fall and as near the optimum time of planting as was possible.

Table III shows the average hay yields for six years, and the average seed yields for five years when fall seeded alone. Both hay and seed yields show a gradual increase from the 40-pound rate to the 80-pound rate, and then a drop for the 100-pound rate. The 80-pound rate is the most profitable to use unless the seed is high in price.

TABLE III. RESULTS OF RATE OF PLANTING TRIALS WHEN VETCH WAS SOWN ALONE

| Rate of seeding pounds per acre | Hay production (6 year average) Tons per acre field dry | Hay production (6 year average) Tons per acre dry matter | Seed production (5 year average) Bushels per acre |
|---|---|---|---|
| *lbs.* | *tons* | *tons* | *bu.* |
| 40 | 3.31 | 2.43 | 22.62 |
| 60 | 3.76 | 2.74 | 26.58 |
| 80 | 4.06 | 2.92 | 29.19 |
| 100 | 3.90 | 2.81 | 28.70 |

**Seeding mixtures.** Vetch may be sown either alone or with a companion crop. For forage, sowing with a companion crop is preferable, because it helps to prevent lodging and increases the yield. In years when insects or disease pests are prevalent, this companion crop very often acts as an insurance, as it is seldom materially injured, while the vetch sometimes suffers. Winter oats, winter wheat, winter barley, and winter rye are used for this purpose. For general purposes, winter oats is best.

Where the crop is to be used for special purposes such as a green manure or cover crop, silage, pasture or soiling crops, use the companion crop which is best suited for that particular purpose. For green manuring or cover crop purposes, barley and vetch or rye and vetch are considered best because of their rapid early spring growth. For silage purposes, generally a mixture of oats and vetch is used since any surplus may be cut for hay or seed. Some growers are using a mixture of wheat and vetch, claiming that it gives a slightly increased tonnage over a mixture of any of the other small grains with the vetch, and because the stiffer straw of the wheat allows less lodging. Winter barley and vetch are a good silage mixture but are poor for hay or seed. Winter barley reaches the hay stage about three weeks before the vetch, so that by the time the vetch is at the hay stage, the barley is ripe and worth little more than straw for forage. The beards are objectionable, being troublesome to the mouths of livestock.

**Separation of wheat and vetch difficult.** Where the crop is to be grown exclusively for seed production purposes, it is considered an advantage to grow the vetch alone. This is especially so when considered from the standpoint of seed cost, difficulty of separating vetch seed from the various cereal seeds, and yields. Oats is comparatively easy to separate from vetch and most ordinary machinery will separate rye from vetch. Wheat and vetch or barley and vetch are very difficult to separate because of their similar size, weight and shape, and special machinery is required to do efficient work.

Table IV shows the hay and seed production of vetch and oats seeded in combination at different rates. In hay yield the 80-40-pound rate gives a very slight increase over that of either the 60-40- and 100-40-pound combinations, but when considered from the standpoint of financial outlay for seed the 60-40-pound rate is most economical. For seed production the 80-40-pound combination proved to be the best when yield of vetch seed is considered, and the 40-40-pound combination the best when yield of oats is considered.

The yield of vetch seed increases as the rate of vetch seeded increases up to and including the 80-pound rate, and the yield of oats seed decreases as the rate of vetch seeded increases. The lighter seedings produce the larger yields of oats. This is largely accounted for by the fact that the increased stands of vetch often choke out or lodge the oats.

TABLE IV. RESULTS OF RATE OF PLANTING TRIALS WHEN VETCH WAS SOWN AT DIFFERENT RATES WITH GRAY WINTER OATS

| Rates of seeding, pounds per acre Vetch | Oats | Hay production 6-year average tons per acre Field dry | Dry matter | Seed production 5-year average bushels per acre Vetch | Oats |
|---|---|---|---|---|---|
| *lbs.* | *lbs.* | *tons* | *tons* | *bu.* | *bu.* |
| 40 | 40 | 3.94 | 2.86 | 20.70 | 42.61 |
| 60 | 40 | 4.31 | 3.14 | 24.76 | 37.81 |
| 80 | 40 | 4.33 | 3.17 | 26.69 | 34.72 |
| 100 | 40 | 4.32 | 3.14 | 23.16 | 29.90 |

Two methods of seeding vetch are generally followed, namely, broadcasting and drilling.

Drilling is preferred because it gives more even and accurate distribution of seed and better covering. Drilling usually requires less seed an acre than broadcasting, although this point depends somewhat on the efficiency of the broadcasting and covering work.

Broadcasting is usually practicsed where only small, rough, or stumpy areas are to be seeded, where the farmer has no drilling machinery, or where a field that has been in a cultivated crop or a spring sown cereal crop is to receive only one disking and that to be after sowing. By some farmers broadcasting is considered to be a more rapid method of seeding because a larger area can be covered in less time and the power used for drilling can be used for covering the seed with implements that will cover more ground in the same time than will the grain drill.

**Sow medium deep.** Vetch when seeded with the ordinary grain drill is usually sown at a depth of from 1½ to 3 inches. There is no particular advantage in seeding deeper than 2 inches. If the land is in good cultural condition, the seedlings of vetch seeded as deep as 4½ inches will start and often reach the surface without any particular difficulty, but such a depth is not recommended. Very shallow seedings are not recommended because very often the young roots are not sufficiently deep in the ground at the time of heavy frosts to prevent the heaving soil from pulling up the young seedlings and destroying considerable numbers of them. Where broadcast seeding is practiced, the depth of seeding is

TABLE V. RESULTS OF SEEDING OREGON VETCH IN DIFFERENT WAYS AND AT DIFFERENT DEPTHS

| Rate of seeding | Depth of seeding | Hay production Tons per acre field dry | Tons per acre dry matter | Seed production bushels per acre |
|---|---|---|---|---|
| *lbs.* | | *tons* | *tons* | *bu.* |
| 80 | Broadcast | 3.44 | 2.44 | 19.96 |
| 80 | Drilling | 3.47 | 2.52 | 23.60 |
| 80 | 1″ drilling | 3.54 | 2.52 | 26.00 |
| 80 | 2″ drilling | 3.63 | 2.63 | 26.42 |
| 80 | 3″ drilling | 3.66 | 2.64 | 26.94 |
| 80 | 4″ drilling | 3.76 | 2.72 | 29.88 |

often very shallow, and it is on these acres that during severe weather the largest percent of plants is injured.

Table V shows the average hay and seed yields of Oregon vetch obtained by seeding in different manners at different depths. These figures show that broadcasting vetch seed does not produce the yields of either hay or seed that any manner of seeding with the drill does. The yields obtained from simply drilling without regard to depth did not produce as large hay or seed yields as did a definite depth of seeding.

Little difference in hay production is shown between the 2-, 3-, and 4-inch sowing.

**Germination and early growth.** Newly threshed Oregon vetch seed practically always has a high percentage of germination. It seldom falls below 97 percent. The percent of hard seed is very low, usually less than 3 percent. In germination trials carried on during the past nine years with seed grown during the various crop years since 1915, it has been found that vetch seed stored under ordinary good storage conditions for six years is reduced in percentage of germination so little that its crop-producing value is practically as good as that of new seed. The amount of dead seed in samples six years old averages 3 percent. Seed nine years old loses 25 percent in germination and the sprouts are weak.

Vetch seed germinates very rapidly. It usually takes from 6 to 10 days, and the young seedlings appear above the ground in from 14 to 16 days. The seedlings from spring sown vetch seed usually appear above the ground from 2 to 3 days earlier than the seedlings from the fall sown seed, because the ground at that time is usually warmer.

**Value of split seed.** Very often in threshing vetch seed there is a considerable percentage of cracked seed. It is claimed by some growers that 50 percent of this cracked seed will produce plants. In germination trials carried on with cracked seeds it was ascertained that in seed chips representing from one-eighth to one-half seed the germination was 7 percent. Where only half seeds were used the germination was 28 percent. Where chipped seeds (usually representing 50 percent or more of each seed) were tested the germination showed 84 percent.

Split vetch seeds usually are half seeds. The germ in about 50 percent of the cases is practically all on one half of the seed. In about 25 percent of the cases it is uninjured and will germinate. Under favorable conditions the majority of the germinating half seeds will produce plants.

**Hay harvest.** The date of harvesting Oregon vetch for hay usually comes between June 20 and July 10, and depends largely on the maturity of the vetch. The stage producing the largest amount of forage of the greatest palatability and highest nutritive value is the time when the lower pods are about two-thirds filled. At this time the plant usually has its last set of flowers, and is entirely green. The lodging is usually at a minimum for the amount of forage produced, and the product when handled and cured properly is light green in color, free from dust, and of pleasant aroma. The figures in Table VI show the average yields of Oregon vetch cut at various stages over a 5-year period.

TABLE VI. AMOUNT OF FORAGE PRODUCED BY VETCH AT DIFFERENT STAGES OF MATURITY, 1919-1924 INCLUSIVE

| Stage of cutting | Tons per acre green | Tons per acre dry |
|---|---|---|
| | *tons* | *tons* |
| 2nd set of flowers in bloom | 11.27 | 1.99 |
| Lower pods one-fourth filled | 12.57 | 2.77 |
| Lower pods filled | 12.15 | 3.43 |

Average five-year yields.

When the vetch is grown with a companion crop the cutting of the crop for hay is usually regulated by the stage of maturity of the grain of the companion crop. It is recommended that the combination crop be cut when the grain is in the soft dough stage. In the case of winter barley and winter rye combinations, the lower vetch pods are generally less than half filled, while with the gray winter oats combination the vetch is at the proper stage for cutting. In the case of winter wheat, which is the latest maturing of the cereals, the lowest set of vetch pods will be filled and the second set will be three-fourths filled.

Where there is a comparatively small amount of lodging there is little difficulty in cutting vetch or vetch and grain with the ordinary mowing machine.

**Cutting "down" vetch.** Where lodging is heavy it is sometimes necessary for men with forks to follow the mower to remove large bunches or to help free the sickle if it becomes clogged.

An extra long dividing board or one equipped with an extra long and heavy pole is often very useful in making a clear path for the next round of the mower.

Vertical sickles attached to the outer end of the cutter bar have been tried at various times to aid in making a clean swath and to prevent clogging. These have not proved successful where the crop has been heavy enough to need any special dividing arrangement.

Where vetch is sown with a companion crop, there is usually less lodging, and cutting is considerably easier.

Vetch, under ordinary conditions, cures quite rapidly. To retain the color as well as the leaves and finer parts of the stems, it is necessary to shock in large shocks as soon as the material is dry enough and let it complete the curing there. Generally the cut material, after becoming thoroughly wilted, is windrowed and allowed to cure until ready to shock. After drying, it may be handled like any other hay, either being put directly in the mow or stack, or baled direct from the field. The latter method usually results in a loss of color and weight, because it must be very dry at time of baling if it is to keep in the bale. It should be stacked or stored as soon as possible after curing. This makes better and brighter hay.

**Harvesting for seed.** The most satisfactory time for harvesting vetch for seed is just before shattering begins. This is at the time that from three-fourths to five-sixths of the pods are ripe. When cut at this stage, the remainder of the pods are well filled, and will mature germinable seed in the shock.

In harvesting vetch for seed the crop should be handled rapidly and carefully to reduce shattering loss to a minimum. In most cases vetch grown alone for seed is badly lodged and generally is quite difficult to harvest. To overcome this difficulty the use of lifter guards and swather are of distinct advantage. The lifter guards lift the material from the ground so that the sickle may have a comparatively clean field to cut. Swathing attachments, of which there are a number on the market, are also of great advantage in vetch seed harvesting. After the material is cut, this attachment rolls it behind the machine out of the way of the horses and machine on following rounds. Where a swather is not used, it is always advisable to follow the machine with forks and move the last swath so that the horses and mower will not run over and shatter the seed on the next round.

**Prevent shattering.** In any method of harvesting that is practiced, all possible precautions should be used to prevent shattering. Shattering not only causes loss of seed but causes considerable difficulty from volunteering. As soon as possible after cutting, the material should be shocked up in large shocks so that the immature pods may mature and shattering be reduced. Seed vetch in the windrow or swath, if handled after it is dry, is sure to shatter badly.

Vetch handled properly does not shatter very badly. If the crop is not cut until the last pods are ripe, the whole plant is practically dead and serious shattering takes place with handling or even with only a dry wind on a hot summer day. When seed vetch ripens in the field, the amount of shattering may be considerably reduced by cutting early in the morning or at any time when there is enough dew or moisture to make the ripe pods tough.

Some vetch seed growers use the binder in harvesting the crop. Where there is a small amount of lodging, or where the crop consists of a small amount of vetch in combination with a large amount of grain and the material to be bound is dry, the use of the binder is quite successful. The binder makes harvesting faster. If the material is not ripe and dry when bound, the bundles may heat and cause moldy seed. There usually will be considerable shattering, especially when the material is dry.

**Threshing.** To thresh vetch most successfully, the straw and pods should be thoroughly dry. Dry vetch threshes more easily, takes less power, and a larger quantity can be run through the machine in a given time.

Any ordinary threshing machine properly handled will thresh vetch successfully. Much depends on the management of the machine while in operation. In some cases the seed cracks quite easily and there is serious loss. Threshing conditions and seed conditions after threshing vary from season to season, and as a consequence the machine operator must adjust his machinery to the current conditions. Efficient threshing involves getting out and saving all the seed and doing a minimum of cracking. Speed of cylinder and number and set of concaves have much to do with efficient operation. Dry vetch may be threshed with a cylinder speed of 700 revolutions per minute and with all concaves removed and replaced with smooth blanks. Tougher vetch requires some concave teeth to hold the vetch while the cylinder teeth whip out the seed. Tougher vetch may also require a higher cylinder speed. Loss by blowing over with straw is easily avoided by proper wind adjustment.

**Avoid cracking seed.** Very often after harvest losses have been held to a minimum up to threshing time, heavy losses result from seed being cracked by the thresher. Often this loss is not shown by an inspection made at the seed spout. An inspection at the blower or immediately back of the sieves will often show considerable loss. More often vetch seed is crushed rather than cracked and the finer particles usually blow over. Losses of as much as 25 percent have been caused by some machines.

Cracking is usually caused by: (1) Too high a cylinder speed. (2) Too many concave teeth or concaves set too high. (3) Sharp corners on steel blanks or grate bars below and behind cylinder. (4) Screens clogged, or too much wind, so that much seed is reelevated to cylinder and rerun through the machine. This is often a result of too many concave teeth cutting the straw fine and of wrong wind adjustment. (5) Screw conveyors set so close to the trough in which they run that seed crushing takes place.

Where vetch has been grown with a companion crop, the same precautions should be taken for the threshing of this combined crop, as are taken for the threshing of the vetch seed. In practically all cases the vetch seed is the more valuable and is the crop that is most desired. Under ordinary conditions when taking these precautions, the seed of the companion crop will thresh in good shape.

**Value of vetch straw.** Vetch straw is usually considered to be of higher feeding value than any other kind of straw, unless it is pea straw. Where the vetch has been cut comparatively early and a considerable quantity of the green straw is combined with the drier straw and the curing has been done during fair weather, much of it will readily be consumed by stock. In many cases it pays to save this straw for the wintering over of sheep or feeder stock. If not used as feed, it makes an excellent fertilizer, used either as bedding for livestock or as a top dressing for land.

The value of vetch straw in comparison to grain straw as a fertilizer is indicated by the following figures. Vetch straw is higher in nitrogen and phosphoric acid than either wheat or oat straw and higher in potash than wheat straw, but only about one-half as high in potash as oat straw.

TABLE VII. FERTILIZING VALUE OF STRAW

| Kinds | Pounds in 100 pounds straw | | |
|---|---|---|---|
| | Nitrogen N | Phosphoric acid $P_2O_5$ | Potash $K_2O$ |
| Vetch | 1.00 | 0.25 (0.11P.) | 0.65 (0.54K.) |
| Wheat | 0.50 | 0.15 (0.07P.) | 0.60 (0.50K.) |
| Oats | 0.75 | 0.20 (0.09P.) | 1.25 (1.05K.) |

Poorly threshed straw may have considerable seed left in it, and there is likely to be volunteering. This is not detrimental where vetch, a cultivated crop, or another forage crop is to follow vetch, but with a grain crop, vetch is usually considered as inseparable foreign material and reduces the price of the threshed grain.

**Pasturing vetch.** Vetch is considered to be a very good pasture crop for all kinds of livestock, but especially so for cattle and sheep. It is very succulent and palatable and will stand considerable pasturing without much injury when the land is not too wet. Green vetch will cause bloat in cattle and sheep. To avoid this, the stock not accustomed to it should not be turned on vetch pasture while very hungry or before the dew is off.

Occasionally vetch planted in the early fall will make a small amount of pasture during late fall and early winter. Pasturing vetch in the fall is not to be recommended generally because the plants may be weakened to such an extent that they cannot stand severe weather, or may be badly trampled if the land is wet.

Spring pasturing is always preferable. At that season the vetch is making a large growth and has the ability to recuperate rapidly. In ordinary years, it will average six inches in height by April 1, and at that time will make an abundance of excellent pasture. If the land at this season of the year is wet, it is best to pasture only with light stock, such as sheep and calves. Heavy animals will cause considerable puddling of the land and may also destroy many plants by tramping them out.

The extent of the pasturing depends altogether on the crop that is to be harvested. If the crop is to be used for a soiling, silage, or hay crop, it is best not to pasture very close and to take the livestock off the vetch early in May. If the crop is to be used as a seed crop, and proper pasturing methods have been practiced, the livestock can be kept on the planting until May 15 or 20. Some growers think it advisable to pasture vetch where the crop is to be used for seed production since it prevents the vetch plant from making such a large growth.

Pasturing of spring planted vetch usually prevents production of either hay or seed.

During years when the indications are that aphis will destroy the crop, it is an excellent plan to pasture it off as rapidly as possible. In some cases, this rather close pasturing will have a tendency to help destroy the aphids, and if they come under control early enough there is a possibility of still being able to harvest a crop for either hay or seed. Generally speaking, after very heavy pasturing to salvage the crop from aphids, good crops are not to be expected.

**Mixture with small grain.** About 75 percent of the acreage usually termed as having been seeded to vetch is seeded to vetch with a companion crop. The companion crop commonly used is winter oats, although winter wheat and winter barley are being grown to an increasing extent.

Where the crop is to be used as forage, it is advisable to sow with a companion crop because the production is greater, there is less lodging, harvesting is easier, and the companion crop acts as a sort of crop insurance, especially during years when the vetch is attacked by insects or disease.

The proportions of seed used in the vetch and grain combinations are usually on the fifty-fifty basis by volume. This means that where a bushel of vetch is used, a bushel of the grain in the combination also is used. This proportion generally gives a well-balanced combination and the resultant crop is usually about equally divided in proportion of vetch and grain.

Occasionally where the mixed crop is to be grown for some special purpose, different proportions are used. Many growers when producing the crop for use by horses, prefer to sow two parts of oats to one part of vetch. This mixture seems more satisfactory for horses because it increases the roughage somewhat and reduces the protein. With vetch and barley for a silage crop, it is preferable to seed one and one-half times as much barley by measure as vetch. The barley grains are usually quite large, and if seeded on the fifty-fifty basis, the relative number of barley plants produced will be too small and may be further decreased by smothering out. For all general purposes, vetch and wheat and vetch and rye are seeded on the fifty-fifty basis by measure.

The mixtures should be made before seeding. Both are then planted at the same operation. A good way is to dump alternate proportions of the seed on a clean, smooth floor. Then mix by thoroughly shoveling over with a scoop shovel. After having been thoroughly mixed, the drill if properly set, will give in practically all cases almost as accurate a rate of seeding as if the various varieties of seeds were sown separately.

As shown by Table VIII, there is from 25 to 30 percent increase in yield of forage for all combination plantings of vetch and grain. The increase in yield is enough higher to make it almost out of the question to plant grains alone for forage in sections where vetch will grow successfully.

TABLE VIII. COMPARATIVE FORAGE YIELDS OF GRAINS, VETCH, AND VETCH-AND-GRAIN COMBINATION SEEDINGS

| Crop | Rates of seeding, pounds per acre Grain | Vetch | Tons per acre green weight | Tons per acre dry weight |
|---|---|---|---|---|
| | *lbs.* | *lbs.* | *tons* | *tons* |
| Gray winter oats | 64 | ---- | 11.89 | 3.55 |
| White winter wheat | 120 | ---- | 10.61 | 3.42 |
| White winter barley | 100 | ---- | 9.67 | 3.14 |
| Winter rye | 84 | ---- | 9.37 | 2.91 |
| Vetch | 80 | ---- | 12.31 | 3.57 |
| Vetch and gray winter oats | 60 | 40 | 15.00 | 4.32 |
| Vetch and white winter wheat | 60 | 60 | 14.72 | 4.28 |
| Vetch and white winter barley | 60 | 50 | 12.23 | 4.10 |
| Vetch and winter rye | 60 | 56 | 15.61 | 4.76 |

All harvested at hay stage.
Figures are for four-year average.

**Vetch as a hay crop.** Vetch alone or vetch with a companion crop, preferably oats, is considered by livestock men to be among the best of the legume or legume and grain hays. The hay, if properly handled and cured, is of a bright color, leafy, comparatively fine stemmed, and is high in nutrition and palatability. All kinds of livestock do well on it and will consume large quantities.

The analysis of vetch hay compares very favorably with red and alsike clover and alfalfa. It is higher in crude protein than either of the clovers or alfalfa, and is lower in fat than either of these hays. Table IX gives the analysis of these hays as made by Professor J. S. Jones, Chemist of the Oregon Station. Analyses are made on an air-dry basis on materials grown in the Willamette Valley.

TABLE IX. ANALYSES OF WILLAMETTE VALLEY HAYS

| | Number of analyses | Water | Ash | Crude protein | Ether extract | Crude fiber | Nitrogen-free extract |
|---|---|---|---|---|---|---|---|
| | | % | % | % | % | % | % |
| Alfalfa | 9 | 7.92 | 6.91 | 12.55 | 1.09 | 30.90 | 40.63 |
| Clover, Red | 19 | 8.03 | 6.08 | 10.23 | 1.51 | 26.55 | 47.60 |
| Clover, Alsike | 8 | 8.21 | 6.90 | 9.28 | 1.26 | 30.62 | 43.73 |
| Vetch | 35 | 8.36 | 6.10 | 13.26 | .97 | 25.80 | 45.51 |

The yield of vetch hay varies from 2.5 to 4.5 tons an acre in ordinary years and under ordinary cropping conditions.

Vetch hay is generally fed to dairy cattle in this state. A considerable tonnage is fed to beef cattle, sheep, and horses.

The market value in Oregon of good vetch or vetch and grain hay and good clover hay is practically the same. The price of vetch hay as usually quoted is often somewhat less than first grade clover hay on large central markets. Practically all dealers prefer to handle it to straight grain hay, mixed grass and clover hay, grass hay, or cheat hay. At present, there is very little shipment of vetch or vetch and grain hay from any producing district, although Coast dairymen are beginning to use it in quantity.

In rare instances vetch hay has been considered by farmers to be harmful to stock. This has been due to feeding over-ripe vetch hay to horses and to cows. It appears that the mature, or nearly mature, vetch seed fails to digest and accumulates in the digestive tract, resulting in irritation and occasional death. Vetch is therefore better hay at a less mature stage.

**Vetch as a seed crop.** Vetch when planted alone will usually produce as many pounds of seed per acre as a good crop of winter wheat would if grown on the same land under the same conditions. Where grown in combination with one of the cereals, the production of vetch seed is usually about one-third less than where grown alone. The difference in vetch production is made up by the production of the cereal, which in general is about two-thirds of the normal production of that grain when seeded alone.

The value of vetch seed during individual years varies considerably. The average price is about four cents a pound, while the price for various individual years has varied from two and one-half cents to twelve cents a pound. These two prices are extreme and depend on the production, local demand, outside market, and importations from foreign countries. In general, the market value of vetch seed is about three times that of wheat. It is an excellent seed crop to grow within market demands. Added to the cash value of the seed is that of the straw for fertilizer and feed and the addition of nitrogen to the soil made by this leguminous crop.

**Feed value of seed.** Vetch seed is principally used for seeding purposes. It has in a few cases been made use of as pigeon feed and is said to give good results. Vetch seed is not very palatable. Various trials have been made with it as a hog feed, either used whole or ground and fed alone, or mixed with some other foods, such as ground barley or oats. In some instances it has been cooked, and in others soaked for feeding to hogs. Its feeding value for hogs is not considered to be nearly as high as that of the cereals, and for best results it is advisable to feed it with a mixture of grain. Where fed alone unground, it is of very little value and where ground or cooked and fed alone, it is only of value as a maintenance food.

**Vetch for silage.** The use of vetch as a silage and soiling crop is constantly increasing because of its ease of culture, its heavy production, and its palatability when used for either of these purposes.

When vetch is to be used as silage or green feed, it is best to sow it with small grain. Wheat, oats, or barley is good when it is to be used for silage, while wheat, oats, or rye is good when it is to be used for green feed.

The proper stage to cut vetch or vetch and grain for silage is at the time the lower pods are two-thirds filled, to filled. The crop, when cut at this stage, usually gives a maximum tonnage, and is sufficiently mature and yet succulent enough so that when it is put into the silo it ferments properly and produces a mildly acid, very palatable product. If harvested and put into the silo when rather immature, there is a probability of its becoming slimy and unpalatable. If cut when quite mature, it is sometimes hard to tramp the material in the silo solidly enough to exclude the air, and molding may take place. Palatability and digestibility may be reduced because of over-maturity, especially in the case of the seed, and extra large quantities of water are very often necessary when such over-ripe material is being put into the silo. The tonnage of rather mature vetch is considerably less than vetch cut at the right stage.

Vetch when siloed at the proper stage and properly handled in the silo makes an excellent quality of silage and many feeders consider it equal to corn. It makes excellent feed for dairy cattle, beef cattle, and sheep. In general, vetch silage is considered to be better than clover silage in that it is easier to preserve, is usually more palatable, and livestock seem to consume it more readily.

The data in Table X show that the chemical analysis of vetch and oat silage is not as good as that of corn silage. The yield per acre of vetch and oats is more than twice that of corn, and the cost per ton of silage about 45 percent less. The yield and cost of production figures balanced against the nutritive value show that a larger amount of nutritives can be produced at less cost per acre for vetch and oats than for corn.

These data should not imply that corn for silage should be eliminated for vetch and oats, because corn as a cultivated crop is necessary in many farm rotation systems.

TABLE X. COMPARATIVE YIELDS, COST OF PRODUCTION, AND CHEMICAL ANALYSIS OF VETCH AND OATS AND CORN SILAGE

| Silage | Average yield per acre | Cost per ton of producing and siloing | Chemical analyses in percent | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Water | Dry matter | Ash | Crude protein | Crude fiber | Nitrogen-free extract | Ether extract |
| | *tons* | | % | % | % | % | % | % | % |
| Vetch and oats | 12.7 | $4.05 | 73.58 | 26.42 | 1.92 | 2.15 | 8.85 | 12.91 | .60 |
| Corn | 5.4 | 7.05 | 74.68 | 25.31 | 1.35 | 2.27 | 5.27 | 15.74 | .70 |

**Summer silage.** Vetch is one of the most useful crops for the production of summer silage. It can be put into the silo from June 25 to July 10 and is ready to feed at once. This provides succulent feed for livestock at the time when pasture is scarce and soiling crops are not readily available. By filling the silo with vetch in the summer and refilling with corn or sunflowers in the fall, the silo can be kept useful throughout the whole year, or when pasture is not available.

Silage making of vetch is similar to that of other crops. It should be hauled from the field as soon after cutting as possible, cut fine through an ensilage cutter, and tramped well in an air-tight silo. The addition of water is often needed if there is not enough moisture in the cut material going into the silo noticeably to moisten the hand. Water may be put on the cut material either as it is being blown from the machine into the silo or after it gets into the silo. The former method is the better where running water is available and where the motor has plenty of power.

Where vetch is cut into the silo very rapidly, there is considerable settling. After two or three days when most of the settling has taken place, it is often advisable to refill to make use of all the silo space.

**Green feed.** Vetch for green feed is usually available as a limited amount of pasture from April 1 to April 15 and an increased amount of pasture from then on. As a green feed crop, it is usually not ready for cutting before May 1. The amount of feed produced before that time is usually small in comparison to the amount that will be produced afterward. Vetch will produce the maximum amount of green feed from June 1 to July 10. During favorable seasons, it is possible to get a small second cutting or a small amount of pasture from the lands that have been cut over during early May.

When handled as a soiling crop, the material should be brought in fresh from the field each day because when piled up it heats very rapidly and decreases in palatability.

Vetch, or vetch in combination with a small grain, will yield from eight to fifteen tons per acre at the silage stage. The amount produced in the form of green feed or soiling crop depends altogether on the stage at which it was cut, and the yield may vary from three to fifteen tons per acre.

Recent trials of mixtures of the various cereals with vetch have shown that barley and vetch, when grown together, make a silage that is considerably higher in nutritive value than silage made from other small grains and vetch. The barley matures earlier than any of the other cereals and makes a larger percentage of grain in the silage. As the barley makes a smaller total growth and is more mature, the total tonnage per acre of barley and vetch is usually somewhat less than where another cereal is used.

**Vetch as a cover and green manure crop.** During recent years, vetch has been gaining increased recognition as a cover and green manure crop, especially for orchards, though probably of equal value for various other types of farming. Because of its rapidity of growth, winter hardiness, and the large amount of growth produced early in the spring, it is one of the best annual legumes to use for cover crop and green manure purposes in Western Oregon. It has a strong rooting system, increases the amount of nitrogen in the soil, and when planted early prevents considerable soil washing.

To produce the largest amount of green material to plow under early in the spring, the seeding must be done as early in the fall as possible so that the plants will have an opportunity to make maximum early growth. In cultivated orchards, it is often possible to make this planting before September 1. On general farm lands, it is usually made from two to four weeks later. The largest growth for these purposes can usually be obtained by seeding between September 1 and 15.

Vetch as a cover crop may be seeded either alone or with a small grain. Usually it is preferable to seed it with a small grain because the amount of material produced is greater, there is less danger of winter killing, and the cost of seeding is usually less. Where the vetch is seeded alone, 60 to 80 pounds is usually sown, and where seeded with a cereal, a bushel of vetch and a bushel of the cereal are combined and seeded at the rate of 60 to 80 pounds an acre. For cover cropping, a mixture of either rye and vetch, or barley and vetch should be used instead of oats and vetch, because either rye or barley makes more early growth than oats and gives more green material to plow under.

**Early growth important.** To be profitable as a cover crop or green manure crop, vetch must make a heavy early growth. On valley loam and hill lands in Western Oregon to be cropped to field crop, it is best that the crop be plowed under between March 20 and April 1, so that there will be enough moisture in the soil for proper decay of the added organic matter. For orchard or small fruit purposes, an earlier plowing is necessary because of greater moisture requirement. If a green manure crop is plowed under too late, and the dry weather sets in, it may result in a reduced supply of moisture to the growing plants and cause detrimental instead of beneficial results during the first year.

Before plowing under a green manure crop, it should be thoroughly disked and cut up as fine as possible. This will aid considerably in turning under and will hasten the processes of decay.

The value of either a cover or green manure crop depends largely upon the type of crop used, the amount of material and the time it is turned under. It is estimated that a growth of vetch or vetch and a cereal at the time of plowing, averaging ten to twelve inches in height, will be as beneficial to the land as ten tons of manure.

It is good practice to give a light application of land-plaster to vetch to stimulate it into increased growth early in the spring, so that a larger tonnage may be available for turning under for green manure or other early growth purposes.

**Vetch in rotation.** Vetch is a comparatively easy annual legume to work into a rotation. In Western Oregon it will successfully follow any other field crop on any type of reasonably well drained land.

Vetch grown for seed is not recommended in a two-year rotation with grain, especially wheat, because the volunteering vetch produces an inseparable mixture and lowers the grade of the grain.

Vetch in rotation with a cultivated crop such as corn or beans can occasionally be used to clean land of weeds or prepare it for other crops.

A three-year rotation to include vetch allows diversity, includes a cultivated crop, and simplifies farming by reducing the number of operations necessary for the production of the three crops. This rotation should include besides vetch, a cultivated crop such as corn, potatoes or beans, and a cereal crop. To avoid loss by the volunteering of the vetch, it should be followed by a cultivated crop which in turn is followed by disking the cultivated crop land and sowing to grain. Barnyard manure whenever available is very helpful and should be added to the land before the production of the cultivated crop.

During the past ten years, crop succession trials using vetch as the basis have been made on the Experiment Station. Five different crops were used, these being vetch, oats, wheat, corn, and potatoes. All the crop material produced by each planting was removed and only the roots and stubble, and in the case of the potatoes the tops, were left on the land. No fertilizer of any kind whatever was added. One series was seeded to vetch continually. The other four series were seeded on alternate years to vetch and to the various other crops mentioned, thus comparing vetch continuously with alternate cropping. Tables XI and XII show the yields of the various crops grown in this trial. The vetch crops produced for ten years on the same areas have shown a decline in yield not accounted for by seasonal conditions. This decline in yield is shown in both hay and seed and is especially pronounced in the latter case.

This indicates that vetch too should be grown in a rotation. While the reduction in yield is not so great as for unrotated cereal crops, there is an argument against such continued cropping at the present time in the tendency for an increase of wild oats. So far, there has been no detrimental effect from either disease or insect pests, but such trouble probably is more likely to develop in those plantings than in plantings where rotation has been practiced.

Where potatoes have been alternated with Oregon vetch on the same land with no fertilizer added, the yield of potatoes has decreased.

The reduction shown in potato yield is doubtless due largely to rather dry summers and to disease in the potatoes in 1923.

In the case of corn and vetch alternating, both crops have remained practically stationary in production. This also is the case with winter oats.

In the case of winter wheat alternating with vetch, the yields have been good. A comparison with Table I shows that the wheat was grown during years of good rainfall, but without doubt the vetch has had a very beneficial effect on the succeeding yield of wheat.

TABLE XI. EFFECTS OF CROP ALTERNATION ON PRODUCTION OF VETCH, WINTER OATS, WINTER WHEAT, CORN AND POTATOES

| Year | Hay | §Vetch seed | Oats seed | Wheat seed | Corn fodder | Potatoes |
|---|---|---|---|---|---|---|
| | *tons* | *bu.* | *bu.* | *bu.* | *tons* | *bu.* |
| 1914-15 | 3.38 | 25.83 | 66.72 | *0.00 | †0.00 | 138.00 |
| 1915-16 | 2.49 | 31.79 | -------- | -------- | -------- | -------- |
| 1916-17 | 2.26 | 23.24 | 84.21 | 37.79 | 7.67 | 193.00 |
| 1917-18 | 1.29 | ‡0.00 | -------- | -------- | -------- | -------- |
| 1918-19 | 3.96 | 30.99 | 83.74 | 54.33 | 7.32 | 170.16 |
| 1919-20 | 3.37 | 21.83 | -------- | -------- | -------- | -------- |
| 1920-21 | 3.52 | 18.00 | 81.56 | 52.16 | 7.50 | 131.16 |
| 1921-22 | 2.14 | 19.16 | -------- | -------- | -------- | -------- |
| 1922-23 | 2.00 | 17.33 | 74.37 | 45.66 | 7.12 | 88.33 |
| 1923-24 | 3.02 | 18.16 | -------- | -------- | -------- | -------- |

*Failure on account of smut. †No yield taken. ‡Failure on account of aphis.
§Vetch continuously on same land. Other crops alternate with vetch.

The comparative yields of vetch hay and seed where grown continuously or alternated with oats, wheat, corn or potatoes, show a decline in yield where alternating with oats and wheat, and a slight increase where alternated with corn. There is very little difference in yield where vetch was alternated with potatoes, and where vetch was grown continuously.

TABLE XII. HAY AND SEED YIELDS OF VETCH GROWN CONTINUOUSLY OR IN ALTERNATION WITH OATS, WHEAT, CORN, AND POTATOES

| Year | Vetch continuously |  | Following oats |  | Following wheat |  | Following corn |  | Following potatoes |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Hay | Seed | Hay | Seed | Hay | Seed | Hay | Seed | Hay | Seed |
|  | *tons* | *bu.* | *tons* | *bu.* | *tons* | *bu.* | *tons* | *bu.* | *tons* | *bu.* |
| 1914-15 | 2.43 | 25.83 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 1915-16 | 2.49 | 31.79 | 2.77 | 38.41 | 2.37 | 30.49 | 2.83 | 38.99 | 3.11 | 38.41 |
| 1916-17 | 2.26 | 23.24 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 1917-18 | 1.29 | ...... | 1.09 | ...... | 1.18 | ...... | 1.45 | ...... | 1.21 | ...... |
| 1918-19 | 3.96 | 30.99 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 1919-20 | 3.37 | 21.83 | 3.01 | 23.33 | 3.15 | 23.66 | 3.64 | 18.49 | 3.10 | 19.33 |
| 1920-21 | 3.52 | 18.00 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 1921-22 | 2.14 | 19.16 | 2.04 | 21.33 | 2.23 | 17.99 | 2.28 | 18.66 | 2.25 | 21.00 |
| 1922-23 | 2.00 | 17.33 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 1923-24 | 3.02 | 18.16 | 2.64 | 19.33 | 2.65 | 18.66 | 2.83 | 21.33 | 2.98 | 27.83 |

No seed harvested in 1917-18 on account of aphis.

**Vetch seed cleaning.** It is not difficult to clean vetch seed from chaff, weed seeds, rye, or oats. Practically any of the ordinary cleaning machinery, well adjusted, will make a 99 percent separation. This, however, is not generally the case where wheat, barley or cockle and vetch are mixed, because the seeds of these plants are very nearly the same size and the same weight, and a screen that will let one of them through will also let the others through.

At present the only practical way of entirely eliminating wheat from vetch seed is by use of the inclined belt cleaner or the spiral cleaner. The spiral cleaner, while doing very successful work, operates slowly, and where there are large quantities of this material to separate it should be put through a screen cleaner beforehand so as to get rid of all dirt, chaff, and small, cracked, immature, or extra large seeds which may be in the lot.

The market demand for clean vetch seed is continually becoming more strict. Vetch seed that shows a purity of 98 percent usually presents no marketing difficulties, but if the purity is less, buyers usually discount heavily. A mixture of vetch varieties is considered by many buyers to be as bad as a mixture of grains. In practically all cases the different varieties of vetch are absolutely inseparable.

**Fertilizers.** Manure is of value in increasing the yield of vetch. Generally there is comparatively little manure used for the direct production of this crop because it is considered more necessary for other crops. It also tends to cause lodging of the vetch. As an indirect aid for Oregon vetch production, it is considered more profitable to use manure for a cultivated crop that may precede a vetch crop.

*Land-plaster.* Gypsum or land-plaster normally has a stimulating effect upon the growth of vetch. Its effect is especially pronounced where vetch is growing on land that is not particularly suited to the crop and where it has a tendency to make a slow growth. In some cases, especially on land that has been well farmed and is of average or above the average fertility, applications of land-plaster have had comparatively little effect in increasing the yield.

Land-plaster, to be most effective, should be applied early in the spring at the rate of from 50 to 100 pounds an acre. The amount depends on the condition of the crop at the time of application and the use to be made of the crop. If the crop appears backward, a heavy application should be used, while if the crop is in good condition a lighter application will suffice. Under practically all conditions, it pays to apply land-plaster to vetch where the crop is to be used for production of forage. On lands in good physical condition and fertile enough to produce a normal crop of vetch seed, heavy applications of land-plaster should not be made, as it often will result in increased vegetative growth and less seed production.

Table XIII shows the comparative yields of hay and seed obtained from vetch grown on land treated with gypsum and ground limestone and from checks.

This trial was continued for four years, during which time the same areas of land were used for each trial. In the case of the limestone applications, this meant that where 2,000 pounds were added yearly after four years a total of 8,000 pounds had been added. During the period of these trials all crop material was taken off the land and no animal or organic fertilizer other than a small amount of crop refuse was added. Four hay crops and three seed crops were harvested. The fourth seed crop was destroyed by aphids.

The figures in general show a slight increase in hay yield by the use of gypsum and limestone. Where gypsum was used, no advantage was gained by using more than fifty pounds per acre. The 50-pound application of gypsum and the 1,000-pound applications of limestone gave increased seed yields, while land given the other rates of application showed decreased yields. In the case of gypsum, the heavier applications probably caused vegetative growth to be made at the expense of seed production.

TABLE XIII. EFFECT OF GYPSUM AND GROUND LIMESTONE ON YIELD OF VETCH

| Fertilizer used | Amount applied per acre | *Hay yield | | | †Seed yield |
|---|---|---|---|---|---|
| | | Tons field dry per acre | Tons air dry per acre | Tons dry matter per acre | |
| | *lbs.* | *tons* | *tons* | *tons* | *bu.* |
| Check | ....... | 3.00 | 2.37 | 2.17 | 27.66 |
| Gypsum | 50 | 3.14 | 2.53 | 2.23 | 27.86 |
| Gypsum | 150 | 2.98 | 2.40 | 2.12 | 26.14 |
| Gypsum | 300 | 3.16 | 2.52 | 2.21 | 24.86 |
| Ground limestone | 1000 | 3.11 | 2.51 | 2.18 | 28.39 |
| Ground limestone | 2000 | 3.22 | 2.59 | 2.26 | 27.18 |

*Average of 4 years yields.
†Average of 3 years yields.

The experiment showed paying results from the 50-pound application of land-plaster for two years, but it appeared that with even this light application, sufficient improvement in soil conditions had developed in this time so that the land-plaster was no longer necessary.

Lime did not pay in any phase of the experiment, and it is doubtful if it is economical to use it on vetch on the gray or lighter valley soils. Vetch appears rather tolerant of slightly acid soil conditions.

## INSECT PESTS, ANIMAL PESTS AND DISEASES OF OREGON VETCH

Vetch is comparatively free from insect and animal pests and the various diseases which attack many of our field crops. There are a few which occasionally do considerable damage. The insect pests are largely confined to aphids and slugs. The animal pests are generally field-mice. The diseases are stem rot and leaf spot.

**Aphids.** Aphids are more troublesome on certain legumes, such as field and garden peas and different varieties of vetches than on most ordinary field crops. Their serious attacks upon these crops are not a yearly occurrence, but come at intervals. During the years of 1912 and 1918, the most serious attacks upon vetch took place, in 1918 practically destroying the crop.

Aphids winter over in the adult stage, usually in waste material or grass and weeds along fence rows and similar places. If the climatic conditions have not been sufficiently severe during the winter to kill them, they attack the young plants as soon as the weather warms up sufficiently and at once begin multiplying. Multiplying very rapidly if not checked they soon increase to large numbers and do considerable damage.

*No practical control.* The control of aphids on vetch is very difficult, and control measures applied to date on vetch have not been successful. Vetch fields are usually quite large, the growth is dense and often rank, and it is seldom that more than 50 percent of the plants may be reached with destroyers or repellants as usually applied.

Several sprays and poisonous dusts have been tried under various conditions. In general, the results obtained have not paid for the cost of the material and its application. Smudging by the use of a heavy smoke produced by burning wet straw and the use of sulfur fumes have also been tried without success. Various mechanical devices have been tried out, but have not proved worth while.

The artificial methods used for the destruction of aphids on vetch are costly, especially where chemicals are used, and from the results so far obtained, their use is not practical. Mechanical means, were they perfected so that in one or two operations over a vetch field the majority of the aphids could be destroyed, probably would be quite successful, but with all the devices used up to the present time the fields generally have to be gone over so many times that the mechanical injury to the plant is considerably greater than the benefit.

At present nature offers the only satisfactory means of combating aphids on Oregon vetch. The ladybird beetle, commonly called "ladybug," and its larvae are natural enemies of aphids, and when they occur in normal numbers will usually control the situation very well. Occasionally there are years when the ladybird beetles are scarce, and it is during these years that aphids often do considerable damage. Another insect, the larvae of the surphid fly, also consumes large numbers of aphids.

Attempts have been made to transfer ladybugs from their natural winter habitat to vetch fields earlier in the season than they normally come. This has not proved satisfactory because they do not remain in the vetch field.

The best farm control measure for aphids is clean farming. This means the cleaning up of all rubbish piles, the mowing or burning out of old fence rows, and destroying all other winter quarters of the adult insects.

Aphid attacks on vetch are easily recognized, and whenever the owner of a vetch field sees that his crop probably will be destroyed before either hay or seed harvest comes, it is best to make use of the crop as forage immediately. If the crop is not large enough to make it possible to harvest for soiling purposes, silage, or hay, it should be used immediately for pasture. Rapid pasturing is necessary because as the number of aphids increases, the palatability of the vetch decreases.

If the attack is early and the crop is not large enough to make pasture, or it is not desired to use it for pasture, it can be made use of as a green manure crop to be plowed under and followed by a cultivated crop.

**Slugs, a new pest.** Another pest which during the past year has attacked vetch in some areas is the common garden slug. The attacks up to the present time have been somewhat localized and in small areas. The attacked areas have been mainly in the vicinity of trash piles, or unkept fence rows, or along other adjacent uncultivated or grass areas. The matter of control generally resolves itself into the cleaning up of these waste places, destroying the natural habitat of the slugs.

Only a small amount of work has been done toward the control of slug attacks in vetch fields. The only remedy that seems to be of any particular value is the use of copper sulfate, either as a liquid spray or in the very finely powdered form and used as a dust directly on the insects themselves, or on the plants or soil which they are apt to travel over within a comparatively short time after application. It is estimated that as a dust 45 or 50 pounds an acre is sufficient, and that when used as a spray, a mixture of 1 pound of copper sulfate to 100 gallons of water will prove of sufficient strength to kill the slugs.

**Animal pests.** During occasional years, there is considerable trouble in vetch fields with field-mice. The mice will destroy the vetch and grain seeds and seedlings. They usually live in colonies near uncultivated areas and destroy considerable areas of vegetation near by. The most efficient control method is the use of poisoned grain.

**Diseases.** The two diseases which attack vetch are stem rot and leaf spot. These diseases are seldom serious, but there are occasional areas and occasional seasons when the attacks are serious enough to be noticeable.

**Stem rot.** Stem rot, as its name indicates, is a rot on the stem or root of the vetch plant, usually occurring near the ground, but may occur anywhere on the stem, especially where the stem is in contact with the ground. It is a fungous disease and seems to thrive best under moist, warm conditions where the air circulation is poor. It usually attacks the plants in the fall, or comparatively early in the spring, and the most serious attacks are usually centered where the vetch has made a very rank growth and lodged considerably. It is apparent that the only practical control method to be used is to prevent excessive early growth of the vetch crop, so as to reduce lodging. This may be done either by practicing later fall seeding, or by making use of the increased early growth for pasture and by a grain support.

It seems probable that this disease might remain over in the ground from year to year, consequently it is advisable that areas attacked by the disease should not have vetch seeded on them for at least two years after the year of attack.

**Leaf spot.** Leaf spot, another fungous disease, causes a small brown spot, generally on the leaflets, but sometimes on stems and pods. These occasionally become so numerous that parts of the plant may turn a reddish brown color and many leaves fall off. Pods which have been attacked by this disease usually produce small, shrunken seeds which are hard to thresh. Leaf spot is of minor importance, and unless exceptionally severe, seldom reduces a forage yield. Occasionally when the pods are attacked, the yield of seed is reduced. There is no specific control method for the checking or elimination of leaf spot. If the indications are that the seed crop is to be damaged to a considerable extent by this disease, it is advisable to harvest the crop for forage instead of seed.

## VARIETIES OF COMMON VETCH

The general name, Common vetch, covers a large number of varieties and strains. Some of these varieties are very distinct and are easily segregated. Others have only minor differences, and considered commercially all come under the same class.

During the period of the vetch investigational work at this Station, a large number of varieties and strains of Common vetch have been grown for comparison with the commercial variety of Common vetch. Most of these have not shown any particular advantage over this variety, and there have been some that were not as good. There have been a few varieties which have shown up rather conspicuously. After several years' trial, these have proved to be well suited, not only to the usual uses for Common vetch, but to other specific cropping advantages. The best of these types are *Vicia sativa* 13420, *Vicia sativa* 13430, *Vicia sativa* 02831, and Pearl vetch.

**Vicia sativa 13420.** This is the highest producing of the most winter hardy varieties of Common vetch. In Oregon there is comparatively little difference in winter hardiness of the different varieties, but in sections having more severe climates, the factor of winter hardiness is often the determining factor as to whether or not the crop shall be grown.

In plant characteristics this variety differs very little from the ordinary Common vetch. Its date of maturity is usually about one week later. Cultural practices for growing this variety are the same as for Common vetch. Forage and seed yields are equal to those of Common vetch.

**Vicia sativa 13430** is the earliest maturing variety of Common vetch, and for that reason is of particular advantage to those desiring an early pasture or soiling crop, or to the grower of cover or green manure crops. As a hay crop, it may be at a slight disadvantage in that its hay stage comes comparatively early, and during some years may be at that stage during the rainy season. In plant characteristics it differs very little from the Common vetch. The seeds of this variety are easily distinguished from Common vetch in that they are considerably lighter in color. The seeds are light mottled brown instead of the usually dark mottled brown or gray colors of the Common vetch. The color of all seeds is uniform. The same cultural practices for the growing of Common vetch are used for this vetch.

**Vicia sativa 02831.** This is probably the latest maturing strain of Common vetch, and is also probably the largest grower. While its period of maturity is late, its rank growing habits give it the ability of producing as large an amount of pasture or other green feed material as early in the season as Common vetch. Its botanical characteristics are very similar to those of the Common vetch, except for the increased size in stem, leaves, pods and seeds, and color of seed. It is finely mottled, bluish gray.

**Pearl vetch** is very similar to Common vetch and at present in some sections is grown as a forage and seed crop. This type differs somewhat from the Common vetch in that the seeds are of a distinctly light pink color and are generally somewhat flattened. The growth is not quite so large. Pearl vetch has shown itself to be the best variety for early spring planting, and will practically always produce a crop, when sown at that time.

The seeds of all varieties of Common vetch are usable for human food. The seed of Pearl vetch is most often used because of its more presentable color and probably also because of its thinner seed coat. When cooked or baked in a similar manner to navy beans, it has a similar taste and appearance, and some people make little distinction between them for table use.

A selection of Pearl vetch, 31084, has during several years' trials proved to be a higher producer than the commonly grown type.

**Vicia sativa 18805** is practically immune from aphid attacks, and during years when aphids were very serious on other types of vetch, this strain remained practically free and produced good crops. In habit of growth, it differs very little from the Common vetch. The same cultural practices used for the Common vetch are applicable to this strain. In botanical characteristics it differs somewhat in that the flowers are pink; the growth is usually not quite so rank; the plants set seed more freely, and the seeds are somewhat angular, reddish brown in color and about one-half the size of Common vetch seed. It is not as hardy as Common vetch.

## VETCH BREEDING WORK

During the years that the vetch trials have been under way, considerable work has been done in the selection of strains of this vetch to secure improvements.

Crossing the various varieties of vetch has proved a difficult problem, and attempts along this line have been failures.

The most progressive work in the breeding of vetches has been done by selection and at present several very good strains are under observation which show evidence of being superior to those now grown. The number of selections that may be made from Common vetch are practically unlimited because of the great variations that occur. The final problem remains to select and test those which show an improvement over the original strains.

The *Vicia sativa* 13420, 13430, 02831, 31084 and 18805 are the results of selection, and at the present time are considered to be the best five from approximately 1,000 selections.

Considerable work was done at the Oregon Station in selecting types of Common vetch for high protein content. There is a difference in protein content of various types. The higher protein content is usually associated with small plants and when the crop was taken as a whole and acre yields considered, the amount of protein per acre of vetch was not increased.

Station Bulletin 214 June, 1925

# Oregon Agricultural College

# Experiment Station

# Blight Resistance in Pears and Characteristics of Pear Species and Stocks

By

F. C. Reimer

1885

CORVALLIS, OREGON

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# SUMMARY

Pear Blight is probably the most destructive disease affecting fruit trees in America. This disease attacks the blossoms, shoots, large branches, trunks and root systems.

The best varieties of American and European pears are susceptible to this disease.

At present the only successful method of combating blight consists in promptly cutting out all the affected parts and disinfecting the wounds. This method is successful when the work is promptly and thoroughly done by experienced workmen. It merely reduces the losses from this disease, however; it does not entirely prevent them.

The losses are greatest when the trunks and root systems of the trees are destroyed. The trunks of our best varieties of pears and a high percentage of the rootstocks used heretofore are susceptible to this disease.

This Experiment Station has assembled practically all the known wild species of pears and most of the available varieties from Europe, Africa, and Asia. During the past ten years this Station has tested these species and varieties for blight resistance. In every species, except the wild type of *P. ussuriensis,* the vast majority of the seedlings blight readily in the young shoots when inoculated.

There is great variation among the seedlings of each of the important species tested; some are very susceptible, while others are highly resistant.

In every species most of the seedlings show a higher degree of resistance in the older wood than in the young shoots. In a few varieties the older wood has been more susceptible than the young shoots.

The European species have proved far more susceptible to blight than most of the Oriental species.

*P. communis,* which includes the French seedlings and most of the cultivated varieties in America, has proved the most susceptible to blight of all the important species. Not a single immune seedling or variety of this species has been found, although a few varieties and seedlings have shown a very high degree of resistance. When inoculated in the roots 43.8 percent of the seedlings blighted. This species endures shallow and wet soils remarkably well and is resistant to Mushroom Root Rot. It is an ideal stock where root blight is not prevalent.

*P. calleryana* has shown a higher degree of resistance to blight in the trunks and roots than any of the other species suitable for rootstocks. In this species only 9.1 percent of the trees which were inoculated in the roots blighted, and 5.5 percent of the trees proved immune in all parts of the tree. Young trees on this stock are more vigorous than those on any other species. This appears to be the most promising rootstock for Southern Oregon.

The wild type of *P. ussuriensis* has given a higher percentage of resistant seedlings than any other species. This wild type, however, is of little or no value, due to its exceedingly slow growth.

The seedlings of the cultivated varieties of *P. ussuriensis* rank second only to *P. calleryana* in resistance to root blight. In this group 7.6 percent of all the trees inoculated in the trunks blighted into the roots, and 12 percent of all the trees inoculated in the roots developed the disease. One variety of *P. ussuriensis,* however, namely, Ba Li Hsiang, showed a higher degree of resistance in the trunks and roots than did *P. calleryana.* In this variety none of the trunk infections extended into the roots, and only 3.9 percent of the root inoculations were successful. Thirty-two percent of the seedlings of Ba Li Hsiang proved immune in all parts of the tree. The seedlings of some varieties of *P. ussuriensis* are highly susceptible to blight. This stock probably will not prove satisfactory on shallow, very heavy, or wet soils.

In *P. betulaefolia* 23.5 percent of the trees inoculated in the roots blighted. In this species 3.5 percent proved immune in all parts of the tree. This species endures more alkali and propagates more readily from root cuttings than any other species of Pyrus. It is well adapted to sandy and gravelly soils.

In the Japanese pear seedlings, *P. serotina,* 23.5 percent of the trees inoculated in the roots blighted. In this species 2.6 percent proved immune in all portions of the tree. This stock will not thrive on shallow or wet soils and is susceptible to Mushroom Root Rot.

In every one of the five most important species of pears we have found some seedlings which are highly resistant to blight and are extremely vigorous. If these trees can be readily propagated from root cuttings or true to type from seeds, they will prove far more valuable than the variable seedlings now available.

In our inoculation work the following, which belong to *P. communis,* have proved the most resistant of the American varieties: Farmingdale, Longworth, and Old Home. These are the most promising for trunk and framework stocks.

Among all the cultivated varieties inoculated in our collection only six have proved immune; namely, Ba Li Hsiang, Chien Pa, Huang Hsiang Sui, Hung Guar, Ma Ti Huang, and Ta Tou Huang. One other variety, Hsiang Sui, has proved very nearly immune. These varieties all belong to *P. ussuriensis* and are of Chinese origin.

In our variety orchard, which is twelve years old, 34 percent of all the varieties have already been killed as a result of natural infection.

The losses from trunk and root blight can be largely prevented in the newer orchards by planting a resistant variety like Old Home on a resistant rootstock like *P. calleryana* or Ba Li Hsiang and topworking them when three or four years old with the desired commercial variety.

Pear Blight is far more virulent under certain climatic conditions than under other conditions. Our inoculation results will therefore not necessarily apply to regions with climatic conditions different from those of Southern Oregon. It is highly probable that our results will not apply, at least in many instances, to the states east of the Rocky Mountains with their humid summer climate.

# Blight Resistance in Pears and Characteristics of Pear Species and Stocks

By

F. C. Reimer

## PART I. BLIGHT RESISTANCE IN PEARS

### INTRODUCTION

Pear Blight *(Bacillus amylovorus)* is probably the most destructive disease of fruit trees in the United States. It is a native American disease and was first reported along the Hudson River in New York state in 1780, and later from all the other pear districts throughout the eastern states. It is now found from Maine to Florida and from the Atlantic to the Pacific. In some eastern fruit districts the pear industry has been wiped out, or reduced to a negligible quantity, and in all of them it has been seriously injured and extensive planting prevented by this disease. At one time there was a profitable pear industry in the southern states, particularly in southern Georgia and northern Florida. The industry was completely destroyed about thirty-five years ago, soon after this disease became established in those states.

Pear Blight was not native to the Pacific Coast. In California the pear industry became established soon after the state was settled and for many years the disease was unknown there. At that time many growers believed pear blight could not develop, or at least flourish, in the dry summer climate of that state. In 1900, however, the disease made its appearance and proved very destructive in the interior valleys. In two years the pear industry of the San Joaquin Valley was practically wiped out. The disease also proved very destructive in the Sacramento Valley, but there, due to great vigilance, the industry has been saved.

In 1906 Pear Blight first made its appearance in the Rogue River Valley of Southern Oregon. Here the disease has proved very destructive and at one time seriously threatened the pear industry. It causes more or less damage every year, and some years is unusually virulent. Here, as in California, the grower must be constantly on the alert to save his trees.

It would be well if we knew just what monetary loss this disease has brought to the pear industry of America, but no such figures are available. The writer believes that a conservative estimate would place the loss above one hundred million dollars.

A narrow belt along the Pacific Coast, including the coastal valleys of Washington, Oregon, and the northern half of California, has remained remarkably free from this disease. It appears in some of these districts from time to time, but has caused comparatively little loss. Just why this is true is not known. It is probably due to certain climatic conditions prevailing in those districts.

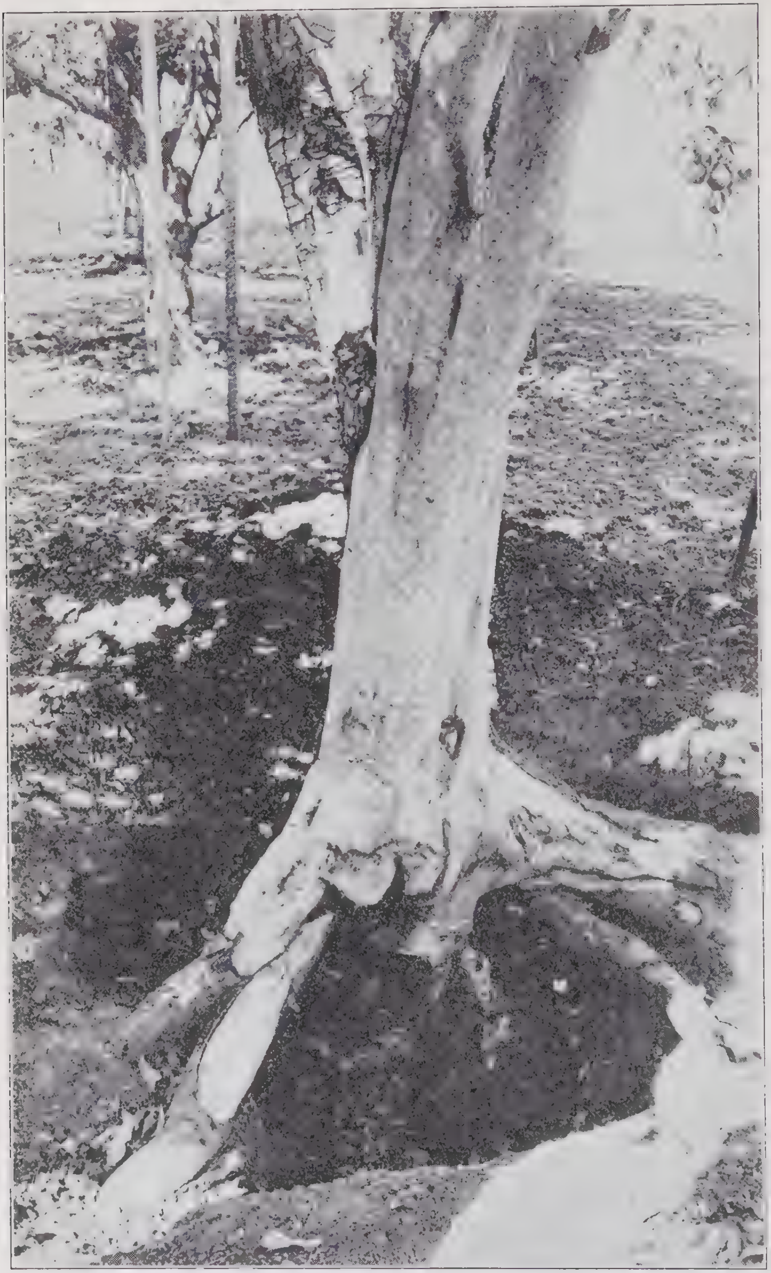

Fig. 1. Bartlett pear tree on French seedling pear *(Pyrus communis)* root treated for bad case of trunk and root blight. A large portion of the bark of the trunk and several roots were removed.

**Description of the disease.** Pear Blight is so well known and so many complete descriptions of it have been published that a brief discussion of the most important characteristics will suffice here.

Pear Blight is a bacterial disease, caused by a germ scientifically known as *Bacillus amylovorus.* The disease attacks all portions of the tree, including the blossoms, fruit, small and large branches, water sprouts, trunk and root system. When it attacks these various parts of the tree it is often given names which would indicate that several diseases are involved. For example, it is known as "blossom blight," "twig blight," "body blight" and "root blight." These forms of blight, however, are all caused by the same organism. Blossom blight is probably the most common, because the tender flowers are readily infected, the organism gaining entrance through the interior parts of the blossoms where the plant is apparently unprotected and where bees and other insects accidentally deposit the germs during the blooming season.

The organism lives in the delicate tissues of the inner bark. It thrives especially in the tissues of the cortical parenchyma and the cambium layer. Since the bacteria are confined entirely to the region beneath the epidermis, it is impossible to control them by spraying. The bacteria multiply with great rapidity, break down the tissues of the plant, and cause the death of the infected portions.

Pear Blight is most active and develops with greatest rapidity during the spring and early summer months. It is well known that the organism thrives best in tender, sappy, succulent tissues and these conditions usually prevail in the plant during the spring and early summer months. The organism is a minute plant and thrives best under circumstances that are most favorable to the growth of pear trees. During the late summer, fall and winter months, when the plant is least active, the organism either dies out or becomes partly or completely dormant. In many cases the organism dies during the late summer and fall in the smaller twigs, but continues to develop slowly in the inner bark of the larger branches, and in the trunk and root system. This, however, is only a temporary check and as soon as favorable conditions are renewed it again develops and progresses with great rapidity.

During the winter months the disease usually harbors in the inner bark of the older and larger portions of the tree, such as the root system and trunk, and in cankers on the larger branches. In the spring these infections become active, often producing considerable ooze laden with bacteria, and bees, ants, thrips and flies distribute it to various portions of the tree, where new infections occur.

The most serious phase of the disease, and that chiefly responsible for its dissemination, is the fact that when one blossom becomes infected bees accidentally distribute the bacteria to thousands of other blossoms throughout the orchard in one day. In fact, if it were not for this accidental distribution by insects, blight would not be a serious factor in pear growing.

During rainy seasons, when a tree once becomes infected, particularly in the upper portions, and the disease is washed down and sprinkled over the blossoms and tender shoots, the infection is far more extensive than it is in dry seasons. This was well illustrated in this Valley during the rainy spring and early summer of 1913. If there is little rain throughout the late spring and summer, when the trees are making only a moderate growth, the disease is far less virulent.

**Methods of controlling Pear Blight.** The present method of controlling Pear Blight is to cut out all affected portions of the tree and disinfect the wounds. In severe cases it is often necessary to remove large sections of the trunk and root system. This method is effective when the work is timely and thorough. It is particularly successful when an entire district follows the plan. Such work is expensive, however, and when a diseased portion is removed the tree is usually injured, since its bearing capacity is reduced. After an orchard has become thoroughly infected, especially where the roots are involved, it is practically impossible to remove every particle of the diseased tissue, since small infections will sometimes be overlooked even by an extremely careful worker, and the most experienced and skillful blight cutter often finds it difficult to decide how far he must cut in order to remove all traces of the disease. This is particularly true of the Bosc tree during the active growing season. In this variety the tissues are often infected for a day or more before they show unmistakable evidence of the presence of the disease.

Furthermore, where the disease is very prevalent and thousands of blossoms, in all parts of the orchard, become infected, it is almost impossible to cut out and destroy every infection. The root systems are often infected for weeks before there are any indications above ground of the presence of the disease. When it is eventually discovered, the root system is often so badly injured that it is impossible to save the tree.

It is therefore evident that this disease is extremely difficult to control. Only the most vigilant growers are successful in doing it.

**Resistant varieties.** Undoubtedly the most promising method of controlling this disease is through resistance. For many years horticulturists have been seeking desirable types which will resist this disease, but up to this time no such desirable commercial varieties have been found. It is true that during recent years a few have been introduced which do not blight seriously. The most resistant among these are Lincoln, Longworth, German Sugar, Burkett, Kieffer, Old Home, Douglas, and Estella. The fruit of these varieties, however, is of such poor quality that with the exception of Kieffer they have not been extensively planted. Kieffer is a hybrid between the Chinese Sand pear and Bartlett and has proved much more resistant to blight than the standard French varieties. Under certain conditions, however, Kieffer blights vigorously and the fruit is poor in quality.

Lincoln has shown a fair degree of resistance and has been quite widely planted in the Middle West. It is not immune, however, and the fruit is of poor quality. Kieffer and Lincoln can never replace such excellent commercial varieties as Bartlett, Bosc, and Anjou.

It is very evident to all pear growers and horticulturists that we need better resistant varieties of pears than those known at the present time. It is a remarkable fact that among the hundreds of French varieties which have been tested in this country not one satisfactory blight-resistant variety of good quality has appeared. It is also interesting to note that all of the resistant European varieties known in this country are of poor quality. At first thought it would appear that blight resistance in the tree is correlated with poor quality in the fruit. This does not necessarily follow, since the Seckel is of excellent quality and the tree shows more resistance to blight than many which produce inferior fruit. It is well known that the Seckel is not immune to Pear Blight, and the fruit is too small for an ideal commercial variety.

It now seems improbable that we shall ever obtain the ideal blight-resistant variety, producing desirable fruit, by merely introducing and testing types from other countries. That such varieties can be produced is now evident to horticulturists and plant breeders. The goal can be achieved only through careful selection and extensive breeding. Heretofore considerable breeding work has been done with this object in view, but up to the present time no satisfactory varieties have been produced. This is due to the fact that most of the pear breeders have used for both parents types which were susceptible to Pear Blight. Little progress could be expected from such methods. In some of this work such varieties as Seckel and Anjou, which show a moderate degree of resistance, have been used; but these belong to the common European species, *Pyrus communis,* which is highly susceptible to blight.

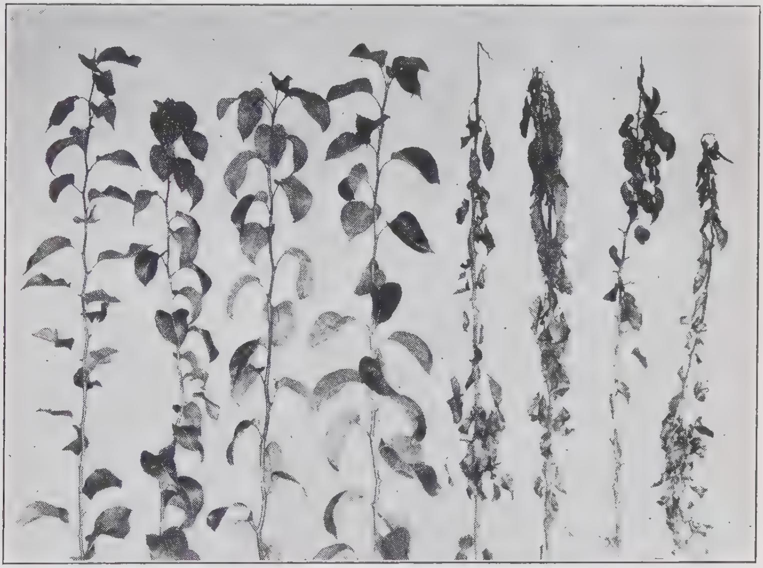

Fig. 2. Showing four Chinese varieties highly resistant to blight. Reading from left to right: Ba Li Hsiang, Ma Ti Huang, Huang Hsiang Sui and Hsiang Sui, and four blighted Bartlett trees. These four Chinese varieties were inoculated on four different dates. On each date a Bartlett was inoculated with the same culture. The Bartletts were all killed while the four *P. ussuriensis* varieties remained immune.

Kieffer is probably the most valuable hybrid which has been grown commercially in this country. One of its parents, the Chinese Sand pear, has proved quite resistant to Pear Blight and seems to be well adapted to conditions in the southern states, particularly the Gulf Coast region, but since the tree is tender in the north, and the fruit is gritty, hard, and of poor quality, it is not a satisfactory variety for breeding purposes.

In 1917 and in 1919 the writer found in northern China and Manchuria certain types of pears which will probably become valuable in breeding blight-resistant varieties. These were introduced into this country and a number of them have proved highly resistant to Pear Blight; some of them produce fruit with certain very desirable characteristics. The fruit is small to medium in size, but has very tender, juicy flesh of fairly good quality, and is free from grit cells with the exception of a few immediately around the core. These varieties are now being extensively used in breeding work at this Station. This work will be discussed under another topic in this bulletin. Experiments of this nature require time, and it may be many years before the ideal variety makes its appearance. In view of what has been accomplished in breeding with other plants and the excellent material now available for this work with pears, the writer believes that the long sought for blight-resistant variety will ultimately make its appearance.

**Resistant stocks.** Since it will probably require many years to produce the ideal, blight-resistant variety of pears, every possible assistance should, in the meantime, be rendered the grower in preventing and controlling this disease. Pear Blight, as has already been stated, often destroys the larger branches, trunk, and root system of our pear trees. This is because our varieties are susceptible to the disease, and the rootstock which has been used very extensively in the past belongs to *P. communis,* a highly susceptible European species. If our pear trees were all on blight-immune rootstocks a large percentage of the losses now sustained would be prevented. Not only would the root system never be destroyed by this disease, but it would harbor no holdover blight, which is now responsible for so many of the new infections above ground.

Furthermore, if the trees of our standard varieties were supplied with an immune trunk and framework and the disease thus confined to the smaller branches, the present losses would be still further reduced.

During the last thirty years the Japanese pear stock, *P. serotina,* has been extensively used on the Pacific Coast, in the Middle West and in the southern states, and a larger percentage of these seedlings are resistant to blight than is found among the French seedlings. But it is not sufficiently resistant, and it is not as well adapted to shallow and wet soils as the French stock.

**Search for blight-resistant pears.** The writer realized that little progress could be made in the search for blight-resistant varieties until there was available in this country a complete collection of all known species of Pyrus, and many of the cultivated types of these various species. At the time this work was begun in 1912 there was no such collection in the United States. It is true that most of the better European varieties had been tested from time to time in this country and some collections are still in existence which include many of these varieties. None of the Experiment Stations, however, possessed more than three or four species of Pyrus, and none of them had a comprehensive collection of the Oriental varieties.

**Pear collection at the Southern Oregon Experiment Station.** During the past twelve years the Southern Oregon Experiment Station has assembled practically all the known species of Pyrus and numerous varieties of all the species from which cultivated types have been developed. This is probably the most comprehensive collection of pears in the world at this time. These species are natives of Europe, Northern Africa, Asia

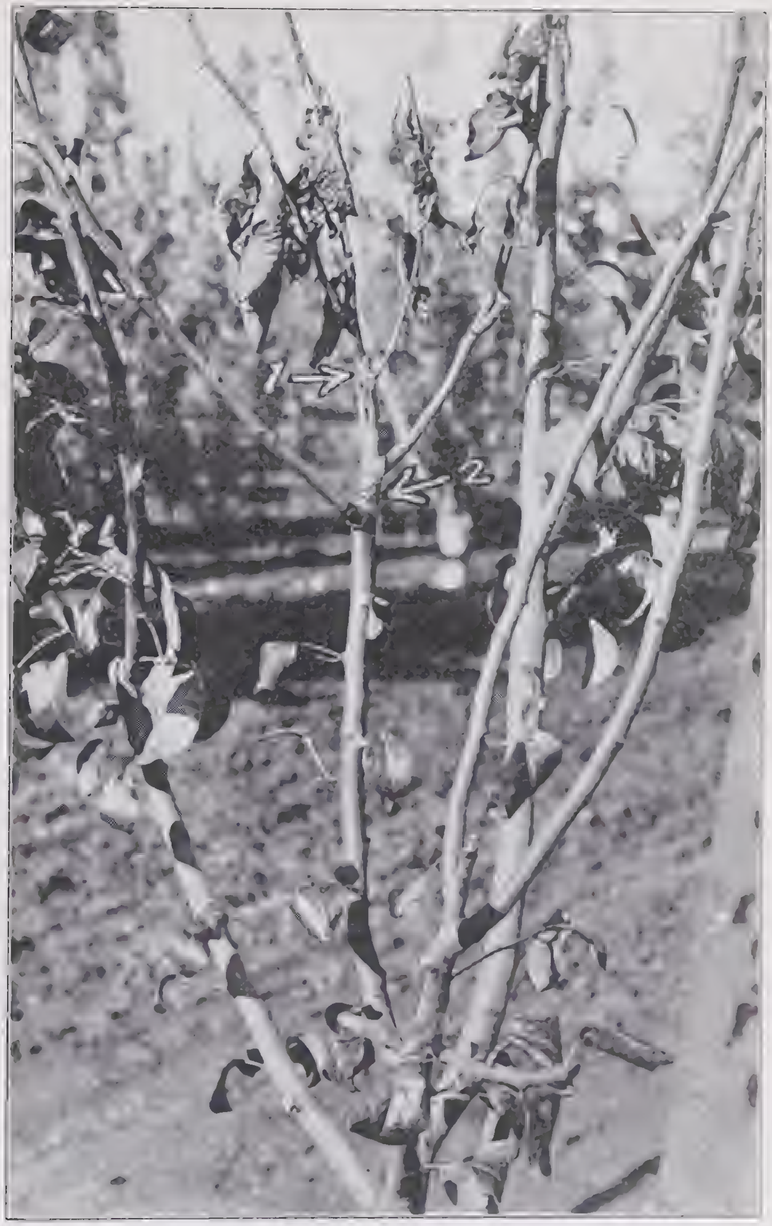

Fig. 3. Showing the Old Home pear tree top-worked with Bartlett at Arrow 1. The Bartlett scion became infected with blight and was killed. The disease extended into the Old Home stock to Arrow 2, a distance of only 2½ inches, where it stopped. This shows the high resistance of the Old Home to blight. If this had been a Bartlett trunk the disease would probably have extended down to the roots.

Minor, and Asia. They have been obtained from various sources, including arboretums, botanical gardens, the United States Department of Agriculture, private collections, explorers, missionaries, nurseries, foreign experiment stations, growers, and through extensive explorations by the writer in Japan, Korea, Manchuria, and China.

In making this collection it has been our aim to obtain and grow as many trees as possible of each of the most promising species. This in order to have available many trees of each for inoculation purposes and for a study of variations in vigor, resistance to blight, and habit of growth.

The writer was fortunate enough to obtain large quantities of seed of the various Oriental types, many of which have proved very valuable. Unfortunately, he has been able to obtain only one type of each of a number of the European and African species. Since all of these have proved very susceptible to Pear Blight, have produced no cultivated varieties, and possess other undesirable tree characteristics, it has not been deemed advisable to make extensive explorations for additional types of these species.

**Testing for blight resistance.** Since Pear Blight is an American disease and unknown in Europe, Asia, and Africa, no evidence could be obtained regarding the resistance or susceptibility of these various species in their native countries. It was therefore necessary to bring them to this country and make many inoculation tests. This work has been conducted at the Southern Oregon Experiment Station on an extensive scale every season during the past ten years. Many of these species have been under test and observation during the entire ten years, a few for the past eight years, and some of the Oriental varieties for a period of only five years. Since the work has been of such magnitude and has extended over such a long period we believe that the results obtained are representative of most of these types.

For several reasons the conditions in the Rogue River Valley are favorable for this work. Pear Blight is extremely virulent here. This is evidenced by the fact that the disease has been found in the orchards of the Valley every year since 1906, and has caused considerable loss each season where it was not properly combated. Under our soil and climatic conditions this disease attacks and destroys all portions of the tree, including blossoms, twigs, branches, trunk, and root system. Trunk and root blight is apparently more prevalent here than in the eastern states, and the disease is more active during the winter months in our mild climate than it is in the colder regions.

The soil conditions under which these trees have been grown are very conducive to the development of Pear Blight. The soil is commonly known as river bottom land and in a soil survey is classed as silty clay loam; it is very fertile and produces vigorous tree growth. For our inoculation tests we have used young trees which have been thoroughly cultivated and fertilized, heavily irrigated and severely pruned, and given all conditions which are conducive to the development of this disease.

**Methods of inoculation.** Fortunately, from the standpoint of testing for blight resistance, pear trees can be easily and readily inoculated on a large scale with the Pear Blight organism. Pure cultures of the disease can be readily obtained, and since the organism multiplies so rapidly and thrives so well in the usual laboratory culture media, large quantities of the culture can be very easily and quickly prepared for inoculating purposes. Furthermore, the disease develops very rapidly, usually within three days after the inoculation is made, hence evidence on resistance or susceptibility can be very quickly obtained. All types in our collection which have shown a high degree of resistance to this disease have been repeatedly inoculated and the tests made as severe as possible.

Pure cultures have been used in practically every case with all of the types covered by these tests. In addition, some of the highly resistant types have been inoculated with quantities of fresh ooze taken from vigorously blighting trees. These ooze cultures, however, did not prove any better than the pure cultures.

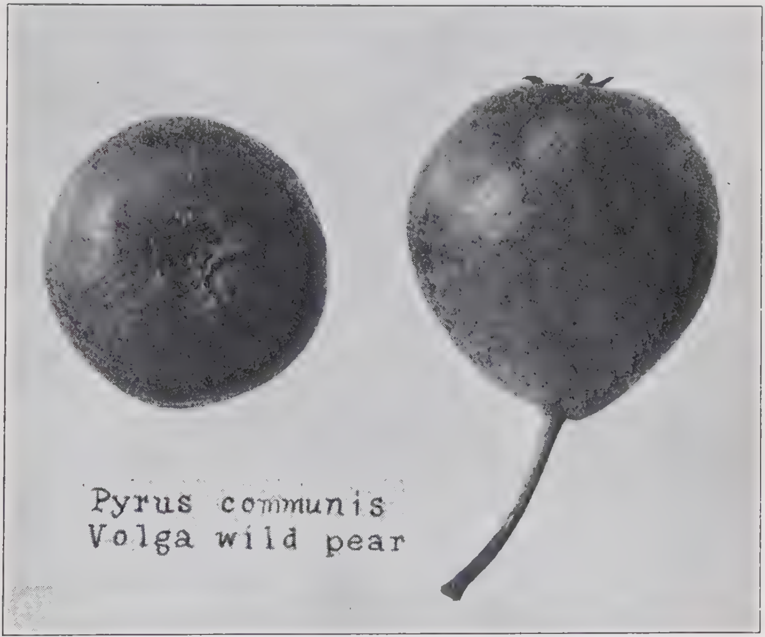

Fig. 4. Fruit of wild French pear *(P. communis)*. This is the fruit of the French seedlings which have been more largely used as stocks for American pear trees than any other species. It is far more susceptible to root blight than any of the other important species.

The usual method of inoculating is to place a drop of the culture on that portion of the tree to be inoculated and then pass a needle through this drop and deep into the bark, from five to ten times. The number of inoculations on all of the varieties and types showing resistance was very large, in some species amounting to thousands during the entire period covered by the test. Every blight culture used was tested by inoculating some susceptible variety like Bartlett, Bosc, or Howell, on the same day and in the same manner as the other varieties or species under test. Whenever these susceptible check trees did not blight readily the culture and results were discarded.

## BLIGHT RESISTANCE IN SPECIES OF PYRUS

The inoculation results obtained with the wild type of the various species of Pyrus are given in Table I. This table gives the name and origin of the species, number of years inoculated, number of dates on which inoculated, age of trees during the inoculation period, number of trees inoculated, and number of tip and trunk inoculations; percent of tip and of trunk infections, and a classification of the latter showing the percent of light, medium, and heavy infections.

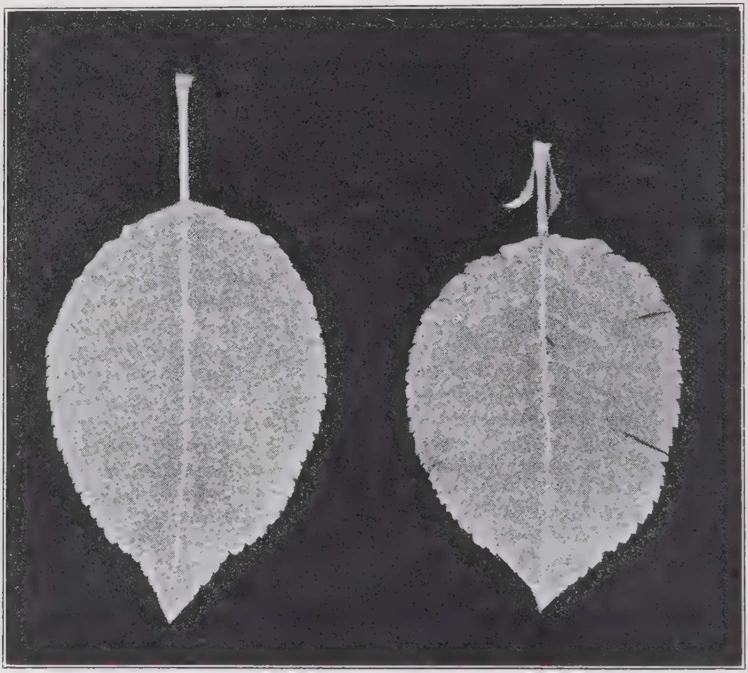

Fig. 5. Typical leaves of a French seedling *(P. communis).*

While at least several trees were inoculated in every species, only one type or variety was available for inoculation in each of the following species: *P. amygdaliformis, P. balansae, P. bretschneideri, P. canescens, P. cordata, P. cotinifolia, P. elaeagrifolia, P. fascicularis, P. glabra, P. heterophylla, P. longipes, P. malifolia, P. mamorensis, P. michauxii, P. nivalis, P. ovoidea, P. parviflora, P. persica, P. salicifolia,* and *P. sinaica.* The several trees belonging to each of these species used in the inoculation work were propagated from one original tree by grafting. It is unfortunate that only one type of each was available, as some of the other types belonging to these species might have shown greater resistance than those used. Since all of these, however, with the exception of *P. ovoidea,* proved highly susceptible, they do not appear very promising.

TABLE I. INOCULATION RESULTS FROM ALL SPECIES OF PYRUS
(Cultivated varieties not included.)

| SPECIES | Age of trees. | Number of years inoculated. | Tip inoculations: Number dates on which inoculated. | Tip inoculations: Total number trees inoculated in tips. | Tip inoculations: Total number of tip inoculations | Tip inoculations: Percent of trees infected in tips. | Trunk inoculations: Number dates on which inoculated. | Trunk inoculations: Total number trees inoculated on trunks. | Trunk inoculations: Total number trunk inoculations. | Trunk inoculations: Percent of trees infected in trunks. | Trunk inoculations: Percent of trees with light trunk infection. | Trunk inoculations: Percent of trees with medium trunk infection. | Trunk inoculations: Percent of trees with heavy trunk infection. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | % | | | | % | % | % | % |
| P. amygdaliformis, Vill. | 2-6 | 7 | 3 | 7 | 25 | 100.0 | 11 | 18 | 76 | 83.3 | 5.5 | .0 | 77.8 |
| P. balansae, Decne. | 1-6 | 7 | 4 | 10 | 20 | 100.0 | 12 | 18 | 67 | 100.0 | 16.6 | 5.6 | 77.8 |
| P. betulaefolia, Bunge. | 2-7 | 10 | 15 | 514 | 4217 | 96.5 | 15 | 850 | 4046 | 93.1 | 8.0 | 14.5 | 70.6 |
| P. bretschneideri, Rehd. | 1-4 | 7 | 3 | 4 | 24 | 100.0 | 14 | 24 | 111 | 50.0 | 37.5 | 4.2 | 8.3 |
| P. calleryana, Decne. | 1-7 | 9 | 19 | 564 | 9125 | 94.5 | 18 | 564 | 5492 | 29.6 | 12.1 | 6.5 | 11.0 |
| P. calleryana-dimorphophylla, Koidz. | 4-5 | 2 | 3 | 37 | 155 | 97.3 | 2 | 36 | 152 | 63.9 | 8.3 | 2.8 | 52.8 |
| P. canescens, Spach. | 2-6 | 6 | 3 | 3 | 15 | 100.0 | 9 | 10 | 30 | 80.0 | .0 | .0 | 80.0 |
| P. communis, Linn. (French seedlings) | 1-7 | 10 | 13 | 220 | 1117 | 100.0 | 20 | 247 | 841 | 93.8 | 9.2 | 10.5 | 74.1 |
| P. cordata, Dasv. | 2-6 | 7 | 3 | 7 | 15 | 100.0 | 14 | 17 | 57 | 100.0 | .0 | .0 | 100.0 |
| P. cotinifolia, Hort. | 2-8 | 8 | 5 | 9 | 25 | 100.0 | 17 | 26 | 100 | 65.3 | 3.8 | .0 | 61.5 |
| P. elaeagrifolia, Pall. | 2-6 | 7 | 3 | 7 | 25 | 100.0 | 12 | 15 | 57 | 93.3 | .0 | .0 | 93.3 |
| P. fascicularis, Hort. | 2-6 | 7 | 4 | 6 | 24 | 100.0 | 14 | 22 | 66 | 77.3 | 18.2 | .0 | 59.1 |
| P. fauriei, Schneid. | 2-4 | 1 | 1 | 14 | 42 | 100.0 | 1 | 14 | 42 | 42.8 | .0 | 21.4 | 21.4 |
| P. glabra, Boiss. | 2-6 | 6 | 5 | 9 | 25 | 100.0 | 8 | 8 | 28 | 100.0 | .0 | 12.5 | 87.5 |
| P. heterophylla, Regel and Schmalh. | 2-6 | 6 | 5 | 10 | 22 | 100.0 | 13 | 17 | 45 | 88.3 | 11.8 | .0 | 76.5 |
| P. hondoensis, Nakai and Kikuchi | 2-4 | 4 | 4 | 10 | 6 | 90.0 | 4 | 4 | 20 | 75.0 | .0 | .0 | 75.0 |
| P. koehnei, Schneid. | 2-3 | 2 | 5 | 5 | 15 | 100.0 | 3 | 11 | 33 | 54.6 | 27.3 | .0 | 27.3 |
| P. longipes, Coos. and Dur. | 2-6 | 7 | 3 | 3 | 13 | 100.0 | 9 | 11 | 37 | 100.0 | .0 | .0 | 100.0 |
| P. malifolia, Spach. | 2-5 | 7 | 4 | 7 | 18 | 100.0 | 14 | 20 | 78 | 90.0 | 20.0 | 5.0 | 65.0 |
| P. mamorensis, Trabut. | 1 | 1 | 1 | 1 | 3 | 100.0 | 1 | 1 | 3 | 100.0 | .0 | .0 | 100.0 |
| P. michauxii, Bosc. | 2-5 | 7 | 3 | 6 | 30 | 100.0 | 10 | 16 | 64 | 93.7 | .0 | .0 | 93.7 |
| P. nivalis, Jacq. | 2-5 | 7 | 3 | 7 | 13 | 100.0 | 9 | 11 | 37 | 100.0 | .0 | .0 | 100.0 |
| P. ovoidea, Rehd. | 2-8 | 7 | 9 | 20 | 122 | 100.0 | 19 | 42 | 200 | 21.5 | 16.7 | .0 | 4.8 |
| P. parviflora, Desf. | 2-8 | 7 | 3 | 7 | 11 | 100.0 | 9 | 15 | 53 | 100.0 | .0 | .0 | 100.0 |
| P. pashia, Buch.-Ham. | 2-5 | 7 | 3 | 8 | 31 | 100.0 | 8 | 9 | 40 | 77.7 | 33.3 | .0 | 44.4 |
| P. persica, Pers. | 1-5 | 5 | 3 | 5 | 13 | 100.0 | 5 | 5 | 19 | 100.0 | .0 | .0 | 100.0 |
| P. phaeocarpa, Rehd. | 2-7 | 7 | 10 | 12 | 44 | 100.0 | 19 | 22 | 87 | 95.4 | .0 | .0 | 95.4 |
| P. salicifolia, Pall. | 2-5 | 7 | 3 | 4 | 20 | 100.0 | 8 | 8 | 30 | 100.0 | .0 | .0 | 100.0 |
| P. serotina, Rehd. (Japanese seedlings) | 1-8 | 10 | 17 | 155 | 935 | 97.4 | 25 | 227 | 984 | 55.9 | 16.3 | 3.1 | 36.5 |
| P. serrulata, Rehd. | 2-7 | 6 | 8 | 177 | 867 | 97.7 | 9 | 177 | 2157 | 72.3 | 32.2 | .0 | 40.1 |
| P. sinaica, Dum. | 2-6 | 7 | 4 | 4 | 25 | 100.0 | 14 | 17 | 63 | 100.0 | .0 | .0 | 100.0 |
| P. ussuriensis, Maxim. (wild) | 1-5 | 5 | 8 | 182 | 266 | 31.8 | 8 | 69 | 217 | 7.2 | 2.9 | .0 | 4.3 |
| P. ussuriensis, Maxim. (seedlings of cultivated varieties) | 2-7 | 6 | 11 | 927 | 7770 | 94.5 | 11 | 1022 | 6433 | 52.2 | 8.1 | 8.0 | 36.1 |

Many types were used in the work with *P. betulaefolia, P. calleryana, P. communis, P. serotina, P. serrulata,* and *P. ussuriensis,* the number of seedlings corresponding with the number of trees used, as shown in Table I.

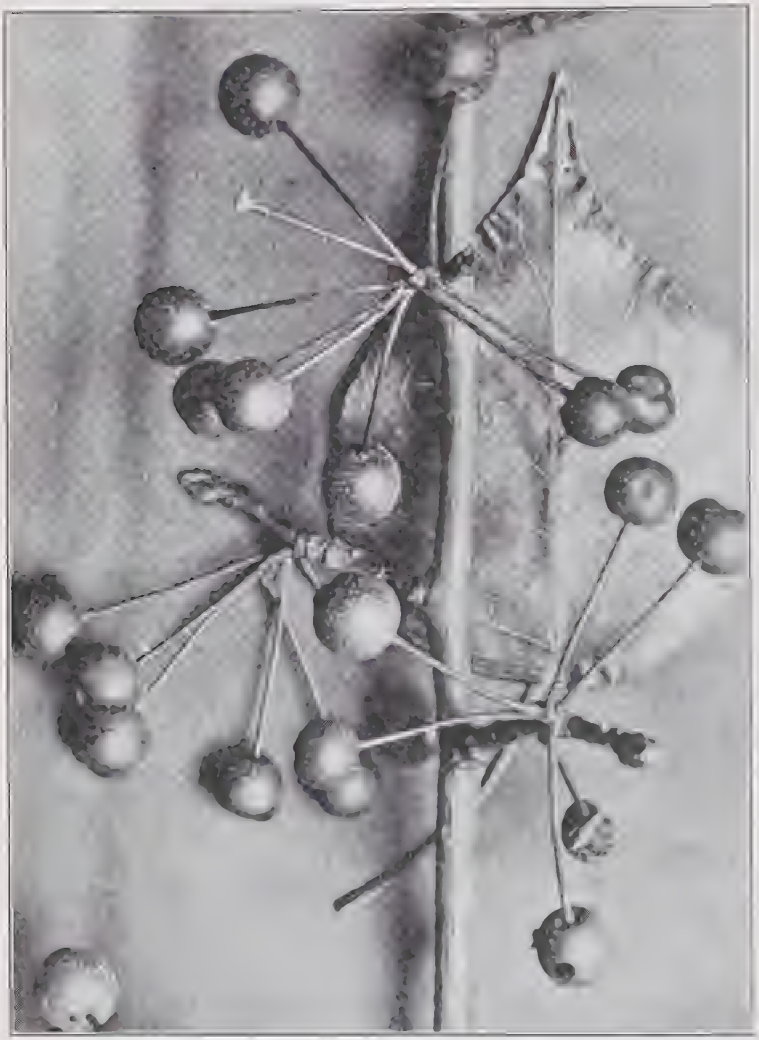

Fig. 6. Fruit and leaf of *P. calleryana.* (Natural size.)

It is evident from the number of dates on which inoculations were made in each species, that most of the trees were inoculated repeatedly. This was done to test their resistance and susceptibility at various seasons of the year, at different ages, and at various stages of growth.

Table I gives a summary of the results obtained from tip and trunk inoculations. Only the more promising species, and especially those of which seedlings were available, were also inoculated in the roots, and the results of this work are given in Table II.

**Results from tip inoculations.** It is evident from Table I that in not a single species did all the individuals prove immune. The results also show that in the following twenty-five species not one immune individual was found: *P. amygdaliformis, P. balansae, P. bretschneideri, P. canescens, P. communis, P. cordata, P. cotinifolia, P. elaeagrifolia, P. fascicularis, P. fauriei, P. glabra, P. heterophylla, P. koehnei, P. longipes, P. malifolia, P. mamorensis, P. michauxii, P. nivalis, P. ovoidea, P. parviflora, P. pashia, P. persica, P. phaeocarpa, P. salicifolia,* and *P. sinaica.* It is probable that immune individuals would have been found in some of these highly susceptible species if a much larger number of seedlings or types had been available for the inoculation work. In all of our work, only seven species have produced individuals which proved immune in the tender tips, and with one exception the number of such immune trees is extremely small in every species. The wild type of *P. ussuriensis* stands at the head of this list with one hundred and twenty-four trees, or 68.2 percent immune. *P. hondoensis* produced one tree, or 10 percent immune. This probably is not representative of the species, owing to the small number of trees tested. For good reasons which will be discussed later, the seedlings of the cultivated varieties of *P. ussuriensis* have been placed in a second group. This group of varieties gave an average of 5.5 percent immune trees. *P. calleryana* gave identical results, with thirty-one seedlings, or 5.5 percent immune. *P. betulaefolia* follows with eighteen trees, or 3.5 percent immune. In degree of resistance there is very little difference between the remaining three species. *P. calleryana-dimorphophylla* produced one immune individual out of thirty-seven, or 2.7 percent. *P. serotina,* which includes the type commonly known among nurserymen as Japanese seedlings, rewarded us with four immune trees, or 2.6 percent. The hybrid group known as *P. serrulata* gave 2.3 percent, or four immune trees.

All the immune trees belong to the Chinese and Japanese species. Not one has appeared among the European, African, or Indian species.

In recording the results, all infections, no matter how slight, have been classed with the susceptible trees. In some species, many of the infections have been very slight, killing the tips for a distance of only one to six inches. This was particularly true with many of the infections in *P. calleryana* and *P. ussuriensis.* Even in the most resistant species, however, the infections in many of the seedlings were severe, killing the shoots and branches to the trunk.

Owing to the great variation in severity of infection on different trees and at various seasons, within the same species, the extent of tip infection has not been given in Table I.

The fact should be borne in mind that the tips of the young tender shoots are usually more readily infected than any other part of the tree. Most of the trees in certain species could be readily infected in the tips, but in many of these it was impossible to produce a single infection in the older and harder wood. This will be evident when the trunk inoculations are considered.

The largest number of trees has been tested and the greatest number of inoculations made in the following species: *P. betulaefolia, P. calleryana, P. communis, P. serotina, P. serrulata,* and *P. ussuriensis.* These include the two species now most extensively used and also all those showing the greatest promise for stock purposes and for breeding work.

With several species the work has been too limited to be conclusive. These appear to be of little value, however, owing to their small size, lack of vigor, and apparent susceptibility to blight.

Fig. 7. Splendid tree of *P. calleryana,* on river bank, southern Shantung Province, China.

In the types in which 100 percent of the trees have proved susceptible, most of the inoculations were successful. In some of these species, notably *P. ovoidea,* it was often necessary to inoculate trees a second time to infect them.

In the most resistant species it is necessary to repeat the inoculations many times during at least two seasons, and at various stages of growth, before a seedling can be pronounced immune. We have found this to be true particularly of *P. calleryana* and *P. ussuriensis.* The apparently immune trees belonging to these and other resistant species have been given the severest tests possible; they have been inoculated repeatedly at various ages, at different stages of growth, and under the most favorable growing conditions. With such treatment some of them resisted all inoculations during the first season and blighted readily during the following year. In a number of cases they resisted all attempts for two seasons and then blighted during the third year. One tree of *P. calleryana* failed to blight when inoculated repeatedly each season for four consecutive years and then became naturally infected in several of the blossoms during the fifth summer. In this tree, however, as in nearly all of those which had resisted the disease for two seasons, the infections were limited to the fruit spurs and the young tender growth of the current season.

From these results it is apparent that the degree of resistance varies, in a measure, with age and seasonal conditions. It is necessary to inoculate a tree repeatedly for several seasons and at various stages of growth before it can be pronounced immune. For this reason, most of the trees which have been recorded as immune in Table I are those which have been very severely tested for several seasons and which have, so far, resisted all inoculations. Additional results emphasizing the effect of varying seasonal conditions on resistance will be presented later in connection with the results obtained with a number of resistant cultivated varieties.

The fact should also be emphasized that not every lot of trees belonging to a certain species will give the same percentage of immune and susceptible trees that we have recorded in Table I. This table is simply a summary of all the results obtained during several seasons. The results obtained with different lots of trees of a certain species often vary greatly. For example, in one lot of twenty-two trees of wild *P. ussuriensis* all proved immune, while in another lot of fifty trees only 46 percent were immune. This is due to the great variation in seedlings, whether judged from the standpoint of disease resistance or other characteristics.

The results from tip inoculations presented in Table I show clearly that the vast majority of trees, in all but one species, blight readily in the tender tips. These results do not necessarily indicate the true value of these species, especially for stock purposes. Undoubtedly the results obtained from trunk and root inoculations are the best index of the value of a species.

**Results from trunk inoculations.** Table I also gives the results obtained from trunk inoculations. Record has been made of the number of trees used in each species, the number of inoculations made, and the percentage of trees infected. The table gives the total percentage of trees infected and also the degree of infection, which is recorded as light, medium, and heavy. All trees in which less than one-third of the trunk blighted have been classified as "light;" those in which from one-third to two-thirds of the trunk blighted have been classified as "medium;" and those in which more than two-thirds of the trunk blighted have been classified as "heavy."

Ten species proved highly susceptible, with a total of 100 percent infection. In eight of these; namely, *P. cordata, P. longipes, P. mamorensis, P. nivalis, P. parviflora, P. persica, P. salicifolia* and *P. sinaica,* all infections were classed as heavy, while in *P. balansae* 77.8 percent and in *P. glabra* 87.5 percent were heavy infections.

The following group of six species ranks next with a total of between 90 and 100 percent trunk infections: *P. betulaefolia, P. communis, P. elaeagrifolia, P. malifolia, P. michauxii* and *P. phaeocarpa.* These also gave a

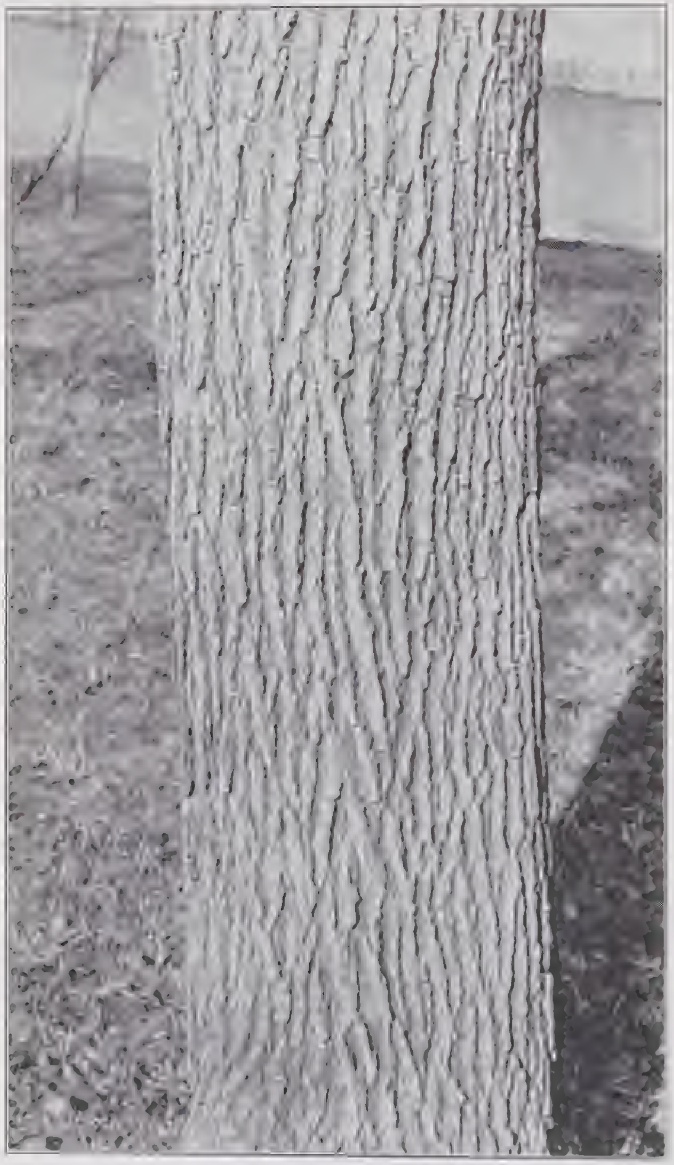

Fig. 8. Showing characteristic trunk of large tree of *P. calleryana.* Compare this with trunk of *P. betulaefolia* and that of *P. ussuriensis.*

high percentage of heavy trunk infection, ranging from 65 percent in *P. malifolia* to 95.4 percent in *P. phaeocarpa.*

A third group of six species gave a total of between 75 and 90 percent of trunk infections. This group includes *P. amygdaliformis, P. canescens, P. fascicularis, P. heterophylla, P. hondoensis* and *P. pashia.*

In the following group of six species from 50 to 75 percent of the inoculated trunks blighted: *P. bretschneideri,* seedlings of cultivated varieties of *P. ussuriensis, P. calleryana-dimorphophylla, P. cotinifolia, P. koehnei,* and *P. serrulata.* In this group *P. bretschneideri* and cultivated *P. ussuriensis* proved most resistant and *P. cotinifolia* and *P. serrulata* most susceptible.

Only four species gave a total of less than 50 percent infection in the trunks. Of these the wild type of *P. ussuriensis* was most resistant, with a total infection of 7.2 percent, and only 4.3 percent heavy infections. *P. ovoidea* ranks second with a total of 21.5 percent and 4.8 heavy infections. *P. calleryana* produced a total of 29.6 percent infections of which 11 percent were heavy. *P. fauriei* gave a total of 42.8 percent infections, half of which were classed as medium and half as heavy. It is possible that the number of *P. fauriei* trees inoculated was too small to give conclusive results. Since this species is a very dwarf grower and produces worthless fruit it was not considered advisable to extend the work with this type.

It is interesting to note the fact that these four most resistant species are all of Oriental origin: *P. ussuriensis, P. ovoidea,* and *P. calleryana* come from China, and *P. fauriei* from Korea. Furthermore, of the seven species which, as a group, ranked second highest in resistance with a total of from 50 to 75 percent infection, six are also of Oriental origin: *P. bretschneideri, P. koehnei,* and *P. serrulata* are natives of China, *P. calleryana-dimorphophylla* and *P. hondoensis* of Japan, and *P. serotina* of both China and Japan. Of the other twenty-two species, all of which gave more than 75 percent trunk infection, seventeen are natives of Europe, two of Africa, one of India, and two of China.

One would expect all of the trees belonging to a species and propagated asexually (by grafting) from one tree, to give similar results when inoculated; that is, if part of the trees are killed one would expect all of them to be killed. This has not been the case, as the degree of trunk infection in many of these species has varied considerably. This variation in resistance is due to differences within the same variety at different stages of growth and particularly at different seasons of the year. A certain tree may be very susceptible during the period of flush growth in spring and early summer, but moderately resistant during the season of slow growth after mid-summer.

Our results also show that it is much harder to infect the trunks than the tender tips of most of the species; in all but eight species the percentage of trunk infection is less than that of the tip infection. As will appear later, the reverse is true in a few varieties.

## BLIGHT RESISTANCE IN THE FIVE MOST IMPORTANT SPECIES OF PEARS

For the convenience of the reader and to facilitate a further comparative study, the results obtained from the five most important species are presented in Table II. The results obtained from the tip and trunk inoculations of these species have already been presented in Table I. In addition, Table II

TABLE II. INOCULATION RESULTS FROM SEEDLINGS OF MOST IMPORTANT SPECIES OF PYRUS

| | | | Tip inoculations | | | | Trunk inoculations | | | | | | | | Root inoculations | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIES AND VARIETIES | Age of trees. | Number of years inoculated. | Number of dates on which inoculated. | Total number of trees inoculated in tips. | Total number of tip inoculations. | Percent of trees infected in tips. | Number of dates on which inoculated. | Total number of trees inoculated on trunks. | Total number of trunk inoculations. | Percent of trees infected on trunks. | Percent of trees with light trunk infection. | Percent of trees with medium trunk infection. | Percent of trees with heavy trunk infection. | Percent inoculated trunks blighted into roots. | Number of dates on which inoculated. | Total number of trees inoculated in roots. | Total number of root inoculations. | Percent of trees infected in roots. |
| | | | | | | % | | | | % | % | % | % | % | | | | % |
| P. betulaefolia | 2-7 | 10 | 15 | 514 | 4217 | 96.5 | 15 | 850 | 4046 | 93.1 | 8.0 | 14.5 | 70.6 | 14.6 | 6 | 66 | 166 | 24.2 |
| P. calleryana | 1-7 | 9 | 19 | 564 | 9125 | 94.5 | 18 | 564 | 5492 | 29.6 | 12.1 | 6.5 | 11.0 | 2.5 | 5 | 175 | 529 | 9.1 |
| P. communis (French seedlings) | 1-7 | 10 | 13 | 220 | 1117 | 100.0 | 20 | 247 | 841 | 93.8 | 9.2 | 10.5 | 74.1 | 39.2 | 10 | 98 | 295 | 43.8 |
| P. serotina (Japanese seedlings) | 1-8 | 10 | 17 | 155 | 935 | 97.4 | 25 | 227 | 984 | 55.9 | 16.3 | 3.1 | 36.5 | 11.8 | 6 | 136 | 291 | 23.5 |
| P. ussuriensis—summary. Seedlings of all cultivated varieties* | 2-7 | 6 | 11 | 927 | 7770 | 94.5 | 11 | 1022 | 6433 | 52.2 | 8.1 | 8.0 | 36.1 | 7.6 | 6 | 180 | 825 | 12.0 |
| P. ussuriensis. Seedlings of individual cultivated varieties— | | | | | | | | | | | | | | | | | | |
| Ba Li Hsiang | 2-5 | 4 | 8 | 215 | 2147 | 67.9 | 6 | 216 | 1671 | 19.9 | 6.9 | 4.2 | 8.8 | .0 | 5 | 103 | 654 | 3.9 |
| An Li | 2-5 | 4 | 4 | 33 | 270 | 100.0 | 5 | 84 | 348 | 71.4 | 7.1 | 4.8 | 59.5 | 8.3 | ...... | ...... | ...... | ...... |
| Chieh Li | 2-5 | 4 | 7 | 139 | 1140 | 93.5 | 6 | 125 | 890 | 76.8 | 7.2 | 10.4 | 59.2 | 10.4 | ...... | ...... | ...... | ...... |
| Chien Pa | 2-5 | 4 | 5 | 95 | 714 | 92.6 | 6 | 76 | 586 | 67.1 | 7.9 | 11.8 | 47.4 | 14.5 | ...... | ...... | ...... | ...... |
| Chiu Suan | 3-5 | 3 | 5 | 45 | 276 | 100.0 | 5 | 30 | 240 | 50.0 | 10.0 | 16.7 | 23.3 | 3.3 | ...... | ...... | ...... | ...... |
| Chiu Tze | 2-5 | 4 | 5 | 85 | 645 | 100.0 | 6 | 111 | 575 | 50.4 | 6.3 | 9.9 | 34.2 | 14.4 | ...... | ...... | ...... | ...... |
| Guar Li | 3-7 | 6 | 8 | 18 | 151 | 94.4 | 7 | 16 | 172 | 37.5 | .0 | .0 | 37.5 | 6.2 | ...... | ...... | ...... | ...... |
| Hua Kai | 3-5 | 3 | 5 | 72 | 447 | 100.0 | 5 | 72 | 328 | 63.8 | 11.1 | 12.5 | 40.2 | 19.4 | ...... | ...... | ...... | ...... |
| Hung Guar | 2-7 | 5 | 11 | 57 | 555 | 98.3 | 11 | 57 | 505 | 65.0 | 15.8 | 1.8 | 47.4 | 1.8 | 1 | 47 | 141 | 25.5 |
| Hu Pi Hsiang | 3-5 | 3 | 5 | 63 | 324 | 100.0 | 5 | 42 | 300 | 57.1 | 11.9 | 14.3 | 30.9 | 2.4 | ...... | ...... | ...... | ...... |
| Man Yuan Hsiang | 2-5 | 3 | 7 | 66 | 517 | 92.4 | 5 | 134 | 263 | 29.0 | .7 | 1.5 | 26.8 | 5.2 | ...... | ...... | ...... | ...... |
| Ta Tze Hsiang | 4-7 | 5 | 6 | 10 | 212 | 90.0 | 7 | 30 | 249 | 50.1 | 6.7 | 6.7 | 36.7 | 3.3 | 1 | 30 | 30 | 6.7 |
| Tzu Ma Li | 4-5 | 2 | 4 | 29 | 372 | 100.0 | 4 | 29 | 306 | 41.3 | 13.8 | 10.3 | 17.2 | 10.3 | ...... | ...... | ...... | ...... |

*The percentages of tip, trunk, and root infections shown are the averages of the varieties tested.

gives the root infections resulting from trunk and root inoculations of these species, and also the results obtained from the inoculations of the seedlings of each of the cultivated varieties of *P. ussuriensis.*

Since some of these species have proved highly susceptible the reader will naturally want to know why they have been included in this list of most important species. They are classed with this group because some of them have shown a high degree of resistance to blight, and others possess certain characteristics which make them valuable from a commercial standpoint. In addition, three of them: namely, *P. communis, P. serotina,* and *P. ussuriensis,* are the parents of the leading commercial varieties in America and the Orient.

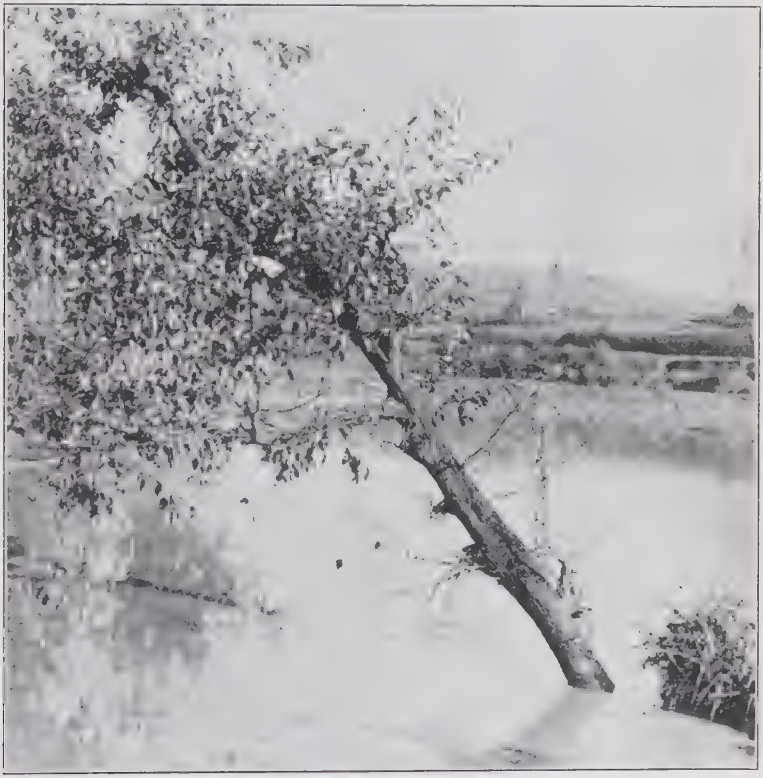

Fig. 9. Showing *P. calleryana* tree growing at the edge of a pond, central China. Part of the trunk immersed in water.

A thorough discussion of the characteristics of each of these species appears in the second part of this bulletin, in which their importance will become apparent.

On the other hand, some of the species which possess a high degree of resistance have not been included because of certain undesirable traits. While the wild type of *P. ussuriensis* has shown a greater degree of resistance than any other species, it cannot be considered important, because its extremely slow growth makes it worthless for stock purposes and its fruit is of too poor quality to be of any value. *P. calleryana-dimorphophylla, P. hondoensis,* and *P. serrulata,* all of which produced some trees that proved immune in the tips, have not been included in the list of most important species because they proved very susceptible in the trunks and manifested certain undesirable growth characteristics. *P. fauriei,* while showing a good degree of resistance in the trunks, has not been included owing to the fact that it is a dwarf and the fruit is worthless. *P. ovoidea* has been eliminated, as only one type has been tested; this is apparently a hybrid and its seedlings are extremely variable.

**Results from tip inoculations.** A summary of the results obtained from the tip inoculations in these species appeared in Table I, and since these results have already been discussed, little further comment regarding most of them is necessary. While in all of these species 90 percent or more of the trees have blighted, it is highly important to remember that four of them—*P. betulaefolia, P. calleryana, P. serotina,* and *P. ussuriensis*—have produced some immune individuals. These trees have proved immune in the trunks and roots as well as in the tips. So far as the writer is aware, these are the first immune pear seedlings that have been found in America among those thoroughly tested by inoculation. While immune pear trees are evidently very rare, it is highly significant to establish the fact that such trees do exist. The writer believes that in the future these immune trees will play a very important part in the pear industry of this country.

Since *P. communis* includes the French seedlings which have always constituted the chief rootstock for pears in this country, special attention should be directed to the results obtained with this species. While not one of the seedlings proved immune, six have shown a high degree of resistance. In three of these most of the inoculations failed. The successful infections have been confined to the tips of the tender current season's growth, in the most severe cases killing these shoots from ten to twenty inches, to a diameter of .2 to .3 inch. In the other three trees the most severe infections have been confined to the current season's growth and to the upper four to six inches of the previous year's wood. All the trunk and root inoculations in these failed. They have been repeatedly inoculated and all the check trees under the same conditions were readily killed by the disease. It is probable that these trees would remain entirely free from the disease when grown under normal conditions and left to natural infection. The propagation work now in progress with them will be discussed later in this bulletin in the section on rootstocks.

The average percentage of infection for the seedlings of the several varieties of *P. ussuriensis* is 94.5 percent. While the seedlings of only thirteen varieties of *P. ussuriensis* were tested, these are the leading varieties in China, hence the results are probably representative of this species. Such marked variation occurred among the seedlings tested that it is deemed necessary to present the results from each of these varieties in the second part of Table II. From these results it is apparent that there is a greater difference among the varieties of this group than there is between the average of this group and any of the other four species. The percentage of trees infected in the different varieties ranges from 67.9 percent in the most resistant to 100 percent in the most susceptible. In six of the varieties 100 percent of the trees blighted. In six other varieties from 90 to 98.3 percent of the trees blighted. One variety, Ba Li Hsiang, is in a class by itself so far as resistance is concerned, since only 67.9 percent of the trees were infected.

In *P. calleryana* 94.5 percent of the trees blighted in the tips. This species and the cultivated varieties of *P. ussuriensis*, therefore, gave identical results and have proved more resistant in the tips than any of the others in this group of most important species.

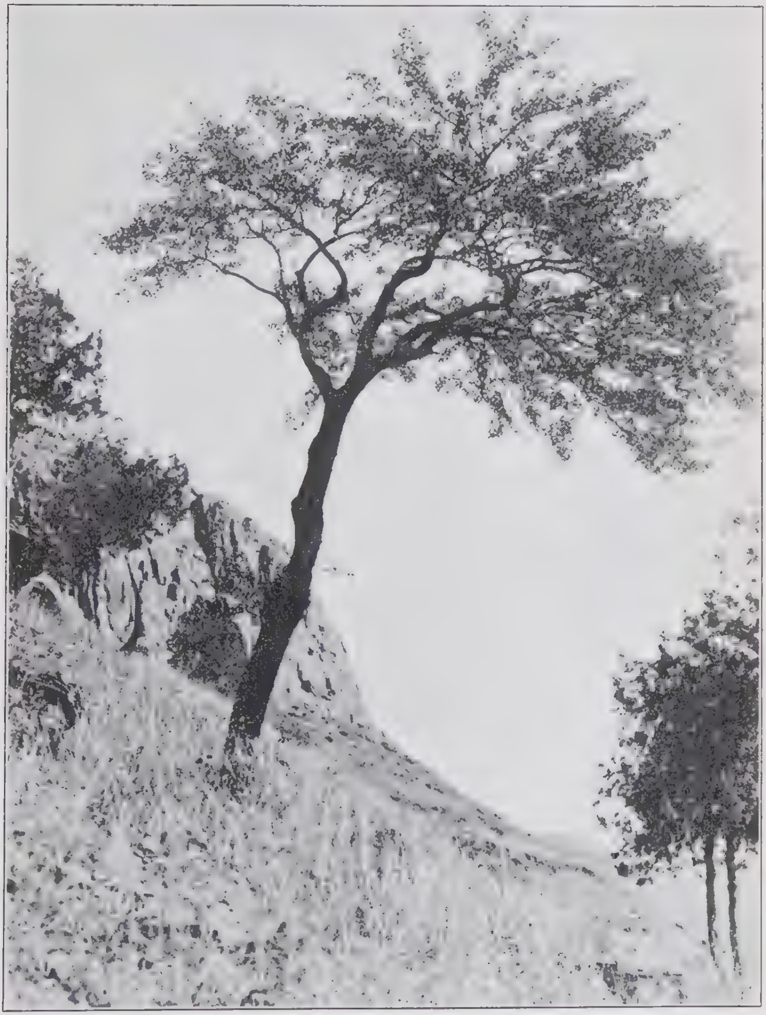

Fig. 10. Tree of *P. calleryana* growing on a dry, rocky mountainside in Shantung Province, China.

*P. betulaefolia* ranks third in resistance with 96.5 percent of the trees infected. It is indeed fortunate that some of the trees of this species have proved immune, since at this Station it propagates more readily from root cuttings than any other species tested. These immune trees may therefore prove of great value as blight-resistant stocks.

In the *P. serotina* group, including the Japanese Sand pears, 97.4 percent of the trees blighted. While this species proved slightly more susceptible in the tips than *P. betulaefolia,* it proved far more resistant in the trunks than that species.

**Results from trunk inoculations.** Of all those species having economic value *P. calleryana* has shown the greatest resistance in the trunks. In this species the total percent of trunks infected is 29.6 percent. Only 11 percent of the inoculated trees show heavy infection. This should be compared with the seedlings of the cultivated types of *P. ussuriensis,* which rank second in resistance and in which 52.2 percent of the trunks blighted and 36.1 percent of them ranked as heavy infections. The degree of infection varies tremendously among the several varieties within this group, and for this reason the inoculation results obtained from the individual varieties are given in the second part of Table II. The percentage of infected trees varies from 19.9 percent in Ba Li Hsiang, which is the most resistant, to 76.8 percent in Chieh Li, which proved the most susceptible. There is therefore a greater difference between the most resistant and the most susceptible variety of this group than there is between this group as a whole and any of the other species. Of the thirteen varieties tested, only four: viz., Ba Li Hsiang, Guar Li, Man Yuan Hsiang, and Tzu Ma Li, showed less than 50 percent infection. *P. serotina* ranks third in resistance, with 55.9 percent of the trunks infected. In the total percentage of trunks infected there is very little difference between *P. betulaefolia* and *P. communis,* the former showing 93.1 percent and the latter 93.8 percent.

It is important to note the percentage of trunk infections rated as heavy in each of these species and varieties. In this respect it is evident that the species again rank as they did for total percentage of trunk infections, although the difference between some of the species is even more marked. It is apparent that *P. calleryana* again stands at the head of the list in resistance, with only 11 percent of the trees showing heavy trunk infection. *P. ussuriensis* ranks second with 36.1 percent, more than three times as many of the trees showing heavy infection as in *P. calleryana. P. serotina* ranks next with 36.5 percent heavy infection. *P. betulaefolia* and *P. communis* gave a very high percentage of heavy infection, with 70.6 and 74.1 percent respectively.

The seedlings of the different varieties of *P. ussuriensis* show great variation in the percentage of heavy infections. Ba Li Hsiang again ranks first in resistance, with 8.8 percent infection. This one variety of *P. ussuriensis* has therefore proved even more resistant than *P. calleryana.* Three other varieties; namely, Chiu Suan, Man Yuan Hsiang, and Tzu Ma Li, gave less than 30 percent heavy infections. In four varieties, Chiu Tze, Guar Li, Hu Pi Hsiang, and Ta Tze Hsiang—from 30 to 40 percent of the trees showed heavy infection. Three varieties, Chien Pa, Hua Kai, and Hung Guar, produced 40 to 50 percent of trees with heavy infection. An Li and Chieh Li proved most susceptible, with 59.5 and 59.2 percent infection respectively. It is interesting to note that all of the varieties of *P. ussuriensis,* with the exception of Ba Li Hsiang, produced a much larger percentage of trees with heavy trunk infection than did *P. calleryana.*

**Root infection resulting from trunk inoculations.** Perhaps the most important results obtained from trunk inoculations are those showing the percentage of trees in which the disease extended from the trunks into the roots. These data are especially valuable since it has become very evident that seedlings should never be used in propagation work for any portion of the tree except the rootstock.

In Table II the last column under trunk inoculations gives the percentage of root infection resulting from trunk inoculations. It is quite apparent from these results that only a comparatively small percentage of the trunk infections extended into the roots, except in *P. communis. P. calleryana* again stands at the head of the list, with only 2.5 percent of the trunk infections extending into the roots. This is approximately one-third as many as in *P. ussuriensis,* which is the next most resistant species, with 7.6 percent. *P. serotina* ranks third in resistance with 11.8 percent of the roots infected. The results from *P. betulaefolia* are interesting since only 14.6 percent of the trees blighted in the roots, while 70.6 percent blighted in the trunks. The French seedlings, listed as *P. communis,* proved the worst blighters, the disease extending into the roots of 39.2 percent of the trees inoculated in the

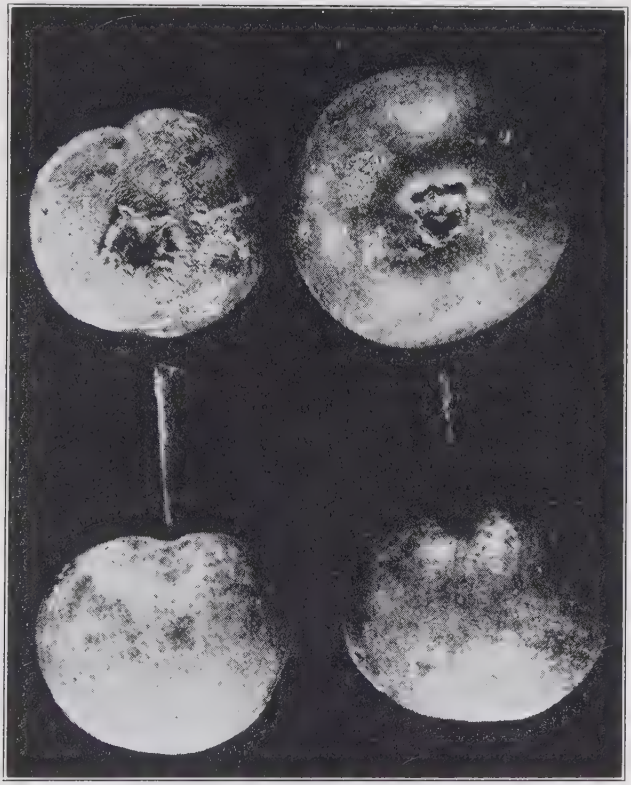

Fig. 11. Fruit of wild *P. ussuriensis.* (Natural size.)

trunks. One of the outstanding results in all of our work has been the very much higher proportion of trunk infection extending into the roots of *P. communis* than in the other four species, which are all of Oriental origin. In the vast majority of heavily infected trees, in these Oriental species, the disease progresses through the trunk with great rapidity, but stops at or just above the surface of the ground. At this point the trees evidently possess a much greater degree of resistance than in the higher portions.

The several varieties of *P. ussuriensis* again show marked differences in resistance. Ba Li Hsiang stands at the head of the list with no infection. The four varieties, Chiu Suan, Hung Guar, Hu Pi Hsiang, and Ta Tze Hsiang, rank next in resistance, each with less than 4 percent infection. Three varieties, An Li, Guar Li, and Man Yuan Hsiang, show from 5 to 8.3 percent infection. The five varieties showing the greatest susceptibility are Chieh Li, Chien Pa, Chiu Tze, Hua Kai, and Tzu Ma Li, with from 10 to 19.4 percent of the trees infected in the roots.

The seedlings of only three varieties of *P. ussuriensis,* Ba Li Hsiang, Hung Guar, and Hu Pi Hsiang, showed a smaller percentage of root infection resulting from trunk inoculations than did *P. calleryana.*

**Results from root inoculations.** The last part of Table II gives the results from the inoculations made directly into the roots. A glance shows that *P. calleryana* again proved the most resistant of these species, with only 9.1 percent of the inoculated trees infected. It is very gratifying that this species should prove to be the most resistant in the roots as well as the trunks. *P. ussuriensis* ranks second in resistance, with 12 percent as the average for the varieties tested. This result is not conclusive, since it is based on work with only three varieties of this group. When judged by the percentage of root blight resulting from trunk inoculations, it is evident that two of these varieties, Ba Li Hsiang and Man Yuan Hsiang, rank among the most resistant, and the other variety, Hua Kai, is one of the most susceptible. There certainly is great variation in the degree of susceptibility of these three varieties of *P. ussuriensis,* ranging from slightly less than 4 percent infection in Ba Li Hsiang, to more than 25 percent in Hua Kai. Two of these varieties, Ba Li Hsiang and Man Yuan Hsiang, proved more resistant in the roots than *P. calleryana,* and the other variety, Hua Kai, far more susceptible. It is of great interest and importance to note the low percentage of root infections resulting from trunk and root inoculations in the seedlings of Ba Li Hsiang. Ba Li Hsiang is one of the few varieties which have proved absolutely immune in all of our inoculation work. This variety evidently is able to transmit this characteristic to its seedlings in a much greater degree than any of the others tested.

It is unfortunate that the other ten varieties of *P. ussuriensis* were not inoculated in the roots. It is evident, however, from the root infections resulting from the trunk inoculations of these varieties that Chiu Suan, Guar Li, Hung Guar, Hu Pi Hsiang, and Ta Tze Hsiang are quite resistant to root blight, while An Li, Chieh Li, Chien Pa, Chiu Tze, and Tzu Ma Li are susceptible. It is certain that the seedlings of those varieties which gave a high percentage of root infection as a result of trunk inoculation should not be used as stocks. In fact, the satisfactory results obtained from Ba Li Hsiang indicate that this variety should be given preference over all other varieties of this species so far tested.

The root inoculations in *P. serotina* and *P. betulaefolia* gave similar results, both species showing a high degree of infection, the former with 23.5 percent and the latter with 24.2 percent of the trees blighted. While this percentage of infection is practically twice as high as the average for the three *P. ussuriensis* varieties, it is still slightly less than that of Hua Kai, which is the most susceptible variety of *P. ussuriensis* tested.

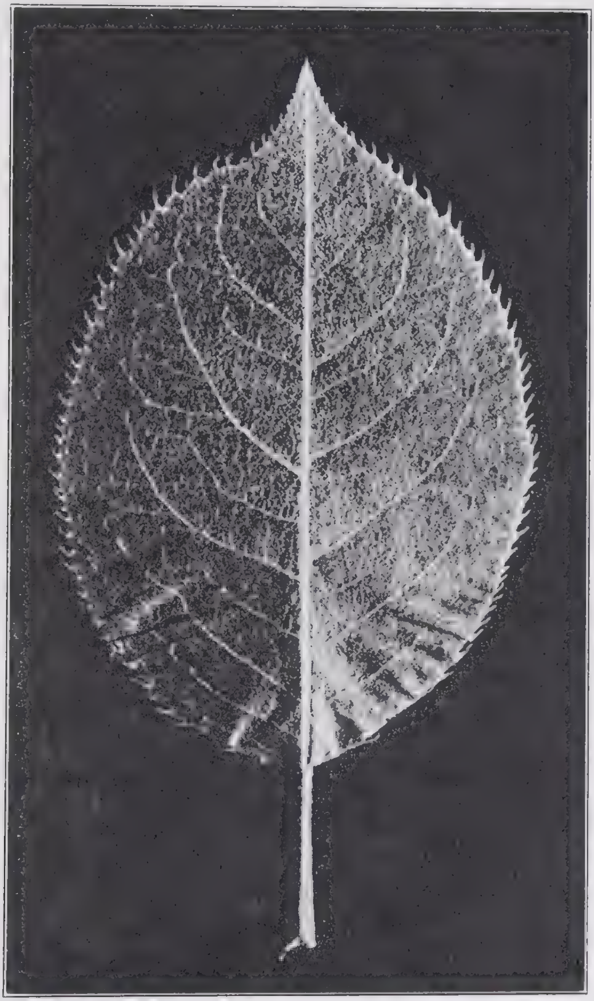

Fig. 12. Leaf of wild type of *P. ussuriensis*.

The *P. communis,* or French seedlings, again proved far more susceptible than those of any other species, with 43.8 percent of the roots infected. This percentage is nearly five times as great as in the case of *P. calleryana. P.*

*communis* has been consistent in its blighting propensities, since it has proved the most susceptible of all the species tested in the tips, trunks, and roots. These inoculation results are also in harmony with the behavior of this species when used as a rootstock in commercial orchards where heavy losses from root blight are often experienced.

The reader must be cautioned not to expect identical results from every lot of seedlings of these particular species and varieties. Unquestionably the results will vary with every lot of seedlings grown from seed collected from different trees of the same species. The results presented show conclusively that there is great variation among the seedlings of each species. The parent seed trees from which the seeds are collected differ similarly. It is highly probable that some of the resistant mother seed trees will give a much higher percentage of resistant seedlings than the average for the species. The preliminary results obtained at this Station indicate that this is the case, at least in *P. ussuriensis.* Seeds from the immune Ba Li Hsiang produce a higher percentage of immune seedlings than those from any other variety. Work is now in progress at this Station to isolate, in each of the most desirable species, resistant mother trees which will have this characteristic of transmitting to their seedlings a high degree of resistance to blight. The writer believes that eventually such trees will be found.

It is equally important to find desirable resistant male trees to serve as pollinators for the mother trees. It is well known that the majority of our varieties and seedlings of pears are self-sterile, and must be supplied with pollen from another variety to produce seed. It is also well known that the male parent is just as potent as the mother tree in transmitting to seedlings the characteristic of resistance or susceptibility. To discover such trees it will be necessary to hand-pollinate the blossoms of the desirable mother trees with pollen from the various promising pollen-bearing trees, and later test for resistance the seedlings of each combination. When such desirable trees are found seed orchards must be planted in isolated places to prevent pollination with undesirable varieties. Until this is done we will never have dependable supplies of seed for stock purposes. The present method of collecting seed indiscriminately from any available tree, or as is more often done, from the pomace at cider mills, is responsible for the high percentage of unsatisfactory trees.

**Pear stocks from root cuttings.** The results presented have repeatedly brought out the fact that there is marked variation in the seedlings of every species of Pyrus, ranging from trees which are highly resistant to those which are very susceptible to blight. Although some species have given a much higher percentage of resistant seedlings than others, the extremes among the seedlings of one species are just as great as those of any other. Each species also shows a wide variation in vigor among the seedlings, some trees being slow growers, while others are extremely vigorous. The root systems vary from types having a long, single, unbranched tap-root to those with a highly desirable well branched system.

The most desirable pear stock is one with all the individuals uniform, resistant to blight, mushroom root rot, crown gall, and woolly aphis; one that is vigorous, hardy, well branched and makes a strong and congenial union with the variety upon it; that will thrive on a diversity of soils, including soils that are shallow and wet as well as those that are deep and well drained, and one that has a long budding season.

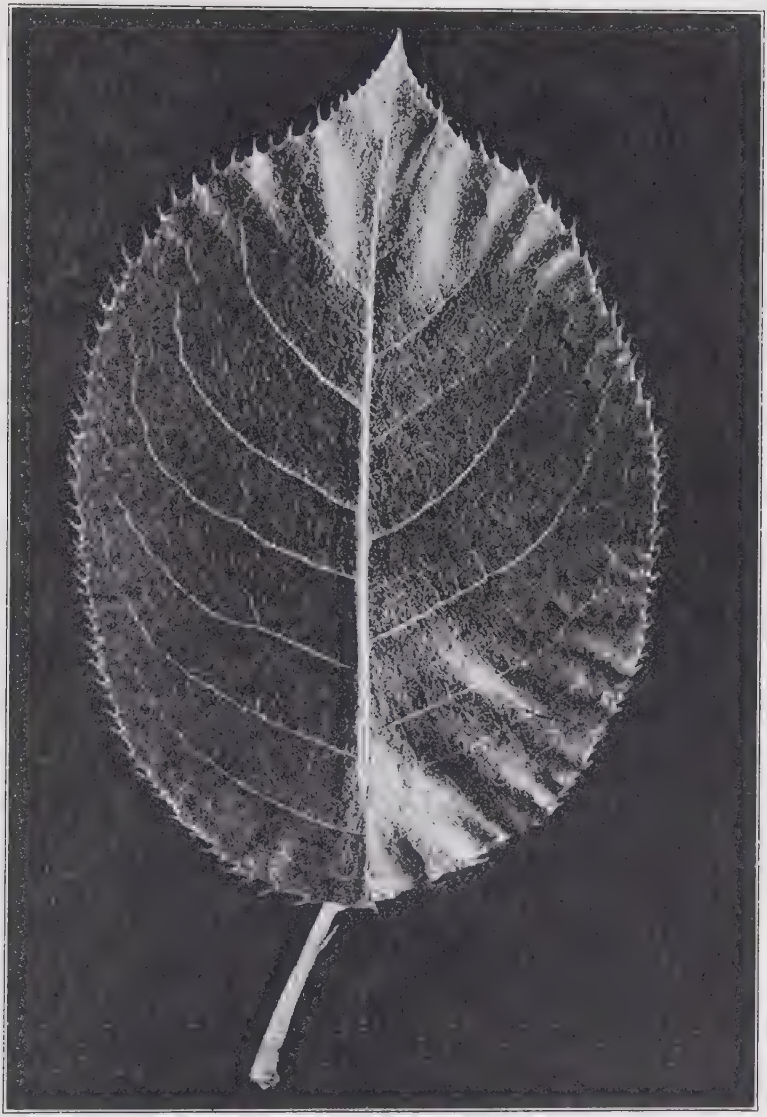

Fig. 13. Leaf of Chieh Li, a cultivated variety of *P. ussuriensis*.

Owing to the variation in seedlings it is likely that it will never be possible to produce seedlings all of which will be uniform and also meet all the requirements of the ideal stock above described.

It now seems probable that the most certain method of obtaining uniform and desirable rootstocks will be from root cuttings. Cuttings made from the roots of a seedling will reproduce that seedling true to type, and it has been demonstrated by this Experiment Station and by the United States Department of Agriculture[8] that seedling pear trees can be reproduced in this manner. Experiments are now in progress to determine the most economical and rapid method of producing stocks from root cuttings on an extensive commercial scale. It has already been determined that some seedlings will propagate more readily than others of the same species. Furthermore, certain species propagate more readily from root cuttings than others. *P. betulaefolia* apparently propagates readily in this manner and in our preliminary work it has given us a better stand of plants than any other species. By this method, however, we have obtained some plants from *P. calleryana, P. communis,* and *P. ussuriensis.*

Among the seedlings of each of the five most important species we have found some which are far superior to others in vigor, resistance to disease, and type of root system. Work is now in progress to propagate these seedlings from root cuttings. In all of the species special attention should be given to the selection of individuals that are vigorous, immune to blight, and possess a well branched root system.

When this method of propagation is adopted it is best to use roots one-fourth to one-half inch in diameter. These are cut into lengths of three to four inches and planted in an upright position, with the upper end of the cutting approximately one-half inch below the surface of the ground. In Southern Oregon the best time to make and plant these cuttings is in the late fall and early winter months.

Certain types of *P. calleryana* have been successfully propagated from branch cuttings in northern Florida, and these trees when transplanted to Oregon have proved very vigorous. This method of propagation has not proved successful in Oregon. Furthermore, it has not been demonstrated that rootstocks grown from branch cuttings will prove as satisfactory and long lived as those propagated from roots. Until this is demonstrated the root cuttings should be given preference. It is well known that some species of plants develop a shallow root system when propagated from branch cuttings.

## BLIGHT RESISTANCE IN VARIETIES OF P. USSURIENSIS

The results obtained from the inoculation work with the leading cultivated varieties of *P. ussuriensis* are presented in Table III. These are the most important varieties of this species grown in northern China, and were propagated by grafting from scionwood collected and brought to this country by the writer. The results herewith presented should not be confused with those presented in Table II, which were obtained from the *seedlings* of some of these varieties. Since these were propagated by grafting, all the trees belonging to any one variety are identical.

TABLE III. INOCULATION RESULTS FROM CULTIVATED VARIETIES OF PYRUS USSURIENSIS
(Grafted trees)

| | | | | Tip inoculations | | | | Trunk inoculations | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VARIETIES | Age of trees. | Number of years inoculated. | Number of dates on which inoculated. | Total number of trees inoculated in tips. | Total number of tip inoculations. | Percent of trees infected in tips. | Extent of tip infection. | Total number of trees inoculated on trunks. | Total number of trunk inoculations. | Percent of trees infected on trunks. | Extent of trunk infection. |
| | | | | | | % | | | | % | |
| Ba Li Hsiang | 1-5 | 5 | 26 | 30 | 79 | .0 | | 25 | 113 | .0 | |
| Chien Pa | 1-4 | 4 | 15 | 28 | 71 | .0 | | 10 | 49 | .0 | |
| Hsiang Sui | 1-5 | 5 | 38 | 77 | 198 | 3.9 | Tip infection 4 to 5 inches | 34 | 130 | .0 | |
| Huang Hsiang Sui | 1-5 | 5 | 25 | 21 | 61 | .0 | | 15 | 53 | .0 | |
| Hung Guar | 1-5 | 4 | 18 | 38 | 89 | .0 | | 12 | 55 | .0 | |
| Lo Suan | 1-4 | 4 | 16 | 23 | 40 | 9.1 | Tips blighted 2 to 3 inches | 7 | 33 | 14.3 | 1 small superficial bark canker. |
| Ma Ti Huang | 1-5 | 5 | 24 | 24 | 68 | .0 | | 12 | 44 | .0 | |
| Mien Suan | 1-5 | 5 | 19 | 15 | 32 | .0 | | 11 | 40 | 9.1 | 1 tree girdled 3 inches to diameter .2 inch. |
| Ta Tou Huang | 1-4 | 4 | 15 | 15 | 44 | .0 | | 7 | 27 | .0 | |
| Chieh Li | 1-5 | 7 | 45 | 77 | 202 | 11.7 | Tips blighted 1 to 4 inches. | 34 | 107 | 9.0 | 2 trees killed to diameter .5 inch. |
| Chiu Tze | 1-4 | 4 | 20 | 16 | 32 | 81.2 | Killed from 5 to 20 inches | 10 | 29 | 90.0 | Killed to stock to diameter 1.1 inch. |
| Hau Kai | 1-2 | 2 | 3 | 3 | 6 | 100.0 | From 1 inch into trunk to diameter .35 inch | 0 | 0 | .0 | |
| Kuan Hung | 1 | 1 | 1 | 1 | 3 | 100.0 | Blighted to rootstock. | 0 | 0 | .0 | |
| Man Yuan Hsiang | 1-5 | 5 | 21 | 16 | 43 | 93.1 | Killed 2 to 30 inches to diameter .4 inch | 9 | 32 | 11.1 | Killed to diameter .5 inch. |
| Nai Tze Hsiang | 1-2 | 2 | 3 | 3 | 5 | 100.0 | Blighted 10 inches into trunk to .7 inch diameter | 0 | 0 | .0 | |
| Nan Li | 1-2 | 2 | 9 | 7 | 8 | 85.7 | Killed 8 to 18 inches | 3 | 9 | 66.7 | Killed 5 inches. |
| Ping Li (Ovoid type) | 1-5 | 5 | 21 | 29 | 71 | .0 | | 16 | 68 | 12.5 | 2 trees killed. 1 tree diameter 1.74 inches. |
| Suan Li | 1-3 | 2 | 4 | 3 | 5 | 100.0 | Killed 4 to 17 inches | 1 | 2 | 100.0 | 2 small cankers. |
| Ta Mo Pan | 2-4 | 3 | 6 | 7 | 23 | 85.7 | Killed from 7 to 24 inches | 3 | 15 | .0 | |
| Tang Li | 1-5 | 5 | 24 | 22 | 54 | .0 | | 17 | 57 | 6.0 | 1 tree killed diameter 1.75 inches. |
| Ta Suan | 1-5 | 5 | 19 | 19 | 42 | 94.7 | Tips blighted 2 to 30 inches | 13 | 42 | 23.1 | Killed to diameter of 1 inch. |
| Tzu Ma Li | 1-5 | 3 | 8 | 8 | 11 | 87.5 | Blighted 6 to 30 inches | 4 | 12 | 25.0 | Killed to diameter of 1.1 inches. |

The table has been divided into two parts, the first part giving results from the nine most resistant varieties and the second those from the more susceptible varieties.

Six of these varieties: Ba Li Hsiang, Chien Pa, Huang Hsiang Sui, Hung Guar, Ma Ti Huang, and Ta Tou Huang, have proved immune. None of the inoculations in either tips or trunks developed the disease. These are the only cultivated varieties of any species, in our entire collection, which have proved immune. One other variety, Hsiang Sui, has also shown a remarkable degree of resistance, since only three trees out of seventy-seven blighted for a distance of only four to five inches in the tender tips, and all the trunk inoculations failed. The results show that this variety is usually immune, but will blight very slightly under exceptional conditions of growth or weather. It is fortunate that this has proved so resistant, as it is one of the two best flavored varieties in this species, and possesses soft, juicy flesh which is free from grit cells except a small number around the core. Another variety, Mein Suan, proved immune in the tips and only one small tree blighted in the trunk, which was girdled for a distance of three inches to a diameter of one-fifth inch. Two trees of Lo Suan blighted in the tips for a distance of two to three inches and one tree produced a small superficial bark canker which readily healed over without the slightest injury to the tree.

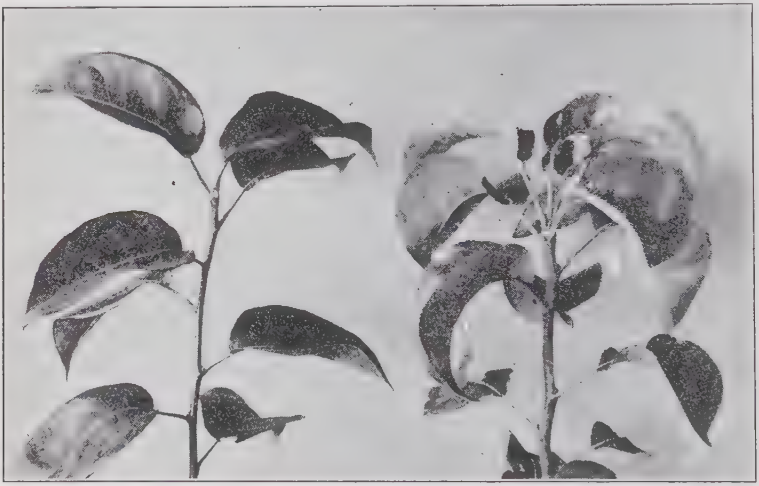

Fig. 14. Showing terminal growth of Japanese Sand Pear *(P. serotina)* on left, and that of *P. ussuriensis* on right. Note the terminal rosette of twisted leaves on *P. ussuriensis.*

In the second group we have placed those varieties of *P. ussuriensis* which have proved most susceptible. One of these, Chieh Li, must, however, be classed as highly resistant. While 11.7 percent of the tip inoculations of this variety were successful, the tips blighted for a distance of only one to four inches. In the trunks only two trees out of thirty-four blighted, and these small trunks were killed to a diameter of only one-half inch. This happened during a period of unusually wet, warm weather. Two other varieties, Ping Li and Tang Li, have so far proved

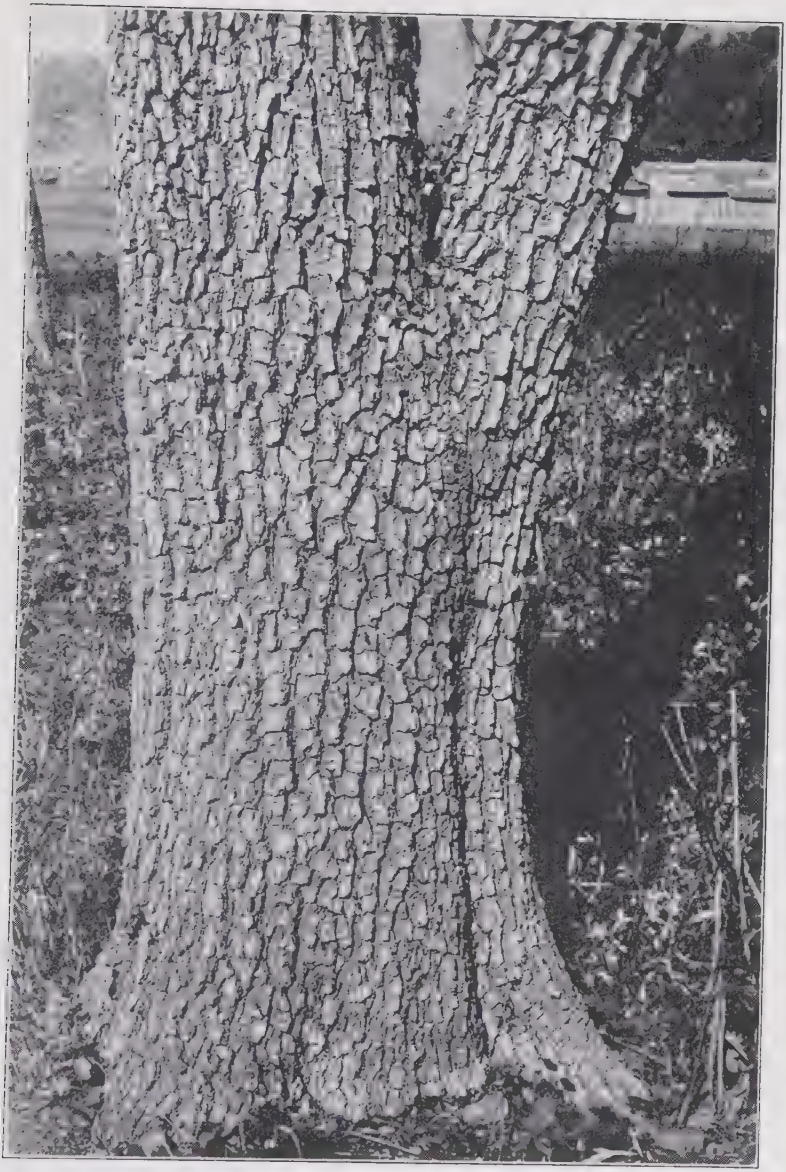

Fig. 15. Typical trunk of old tree of *P. ussuriensis*.

immune in tips, and only one tree of Tang Li blighted in the trunk, while two Ping Li trees were killed as a result of trunk inoculations. It is remarkable that these varieties should prove immune in the tips and occasionally blight in the trunks. It is even more remarkable that these trees should resist all trunk inoculations during the first four years and then blight while making their fifth season's growth.

The other varieties have blighted readily in the young tips, and most of them also in the young trunks. In three varieties no trees were available for trunk inoculation work, and in some of the others such inoculations have been limited. None of the trees tested were more than five years old. It is probable that as the trees grow older some of the varieties will show a higher degree and others a lower degree of resistance, especially in the trunks.

While *P. ussuriensis* has given us the only immune varieties up to the present time, the results show that the species is quite variable, the several varieties ranging from immune to highly susceptible.

Fig. 16. Grove of wild *P. ussuriensis* trees in extreme northern China.

## BLIGHT RESISTANCE IN P. USSURIENSIS HYBRIDS

The writer found eleven varieties of pears in northern China and Manchuria which are apparently *P. ussuriensis* hybrids. While there is no record of their origin, their botanical characters indicate that they are hybrids between *P. ussuriensis* and some other species, probably *P. phaeocarpa*. This group includes the most popular varieties grown in northern China. The inoculation results obtained with these are presented in Table IV.

Not one of these varieties has proved immune. In fact, all of them gave a very high percentage of infection in the tips of young shoots. In six varieties—E Li, Fo Chien Hsi, Mi Li, Pan Chen Ssu, Russet Tang Li, and Yarr Li—100 percent of the tip inoculations were successful. In

### TABLE IV. INOCULATION RESULTS FROM PYRUS USSURIENSIS HYBRIDS

(Grafted trees)

| VARIETIES | Age of trees. | Number of years inoculated. | Tip inoculations | | | | | Trunk inoculations | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Number dates on which inoculated. | Total number of trees inoculated in tips. | Total number of tip inoculations. | Percent of trees infected in tips. | Extent of tip infection. | Total number of trees inoculated on trunks. | Total number of trunk inoculations. | Percent of trees infected on trunks. | Greatest extent of trunk infection. |
| | | | | | | % | | | | % | |
| E Li | 1-3 | 3 | 10 | 10 | 24 | 100.0 | Blighted 8 to 36 inches | 5 | 20 | 100.0 | Killed to stock to diameter 1 inch. |
| Fo Chien Hsi | 1-2 | 2 | 7 | 9 | 27 | 100.0 | Blighted 10 to 33 inches | 1 | 4 | 100.0 | Killed to stock. Diameter 1 inch. |
| Hung Li | 1-4 | 2 | 22 | 21 | 43 | 95.2 | Blighted 3 to 28 inches | 15 | 30 | 33.3 | Killed to diameter .9 inch. |
| Ma Li | 1-4 | 4 | 14 | 13 | 24 | 92.3 | Blighted 6 to 35 inches | 8 | 21 | 50.0 | Killed to diameter .5 inch. |
| Mi Li | 1-4 | 4 | 6 | 9 | 15 | 100.0 | Blighted 7 to 19 inches | 11 | 27 | 27.3 | Killed to diameter 1.2 inches. |
| Pai Li | 1-4 | 4 | 21 | 20 | 58 | 75.0 | Blighted 1 to 17 inches | 16 | 57 | 12.5 | Killed to diameter .3 inch. |
| Pan Chen Ssu | 1-4 | 4 | 5 | 6 | 16 | 100.0 | Blighted 2 to 8 inches | 2 | 6 | 100.0 | Two small cankers. |
| Ping Ding | 1-4 | 4 | 18 | 15 | 30 | 86.7 | Blighted 4 to 27 inches | 6 | 18 | 50.0 | Killed to scion to diameter 1.2 inches. |
| Tang Li-Russet type | 1-2 | 2 | 6 | 9 | 21 | 100.0 | Blighted 4 to 41 inches | 2 | 6 | 100.0 | Killed 16 inches to diameter .5 inch. |
| Tzu Ma | 1-3 | 3 | 8 | 8 | 11 | 87.5 | Blighted 6 to 30 inches | 4 | 12 | 25.0 | Killed to stock to diameter 1.1 inches. |
| Ya Kuang Li | 1-3 | 4 | 19 | 18 | 49 | 83.3 | Blighted 2 to 36 inches | 7 | 20 | 14.3 | Killed to diameter .5 inch. |
| Yarr Li | 1-2 | 3 | 8 | 8 | 24 | 100.0 | Blighted 22 to 60 inches | 2 | 3 | 100.0 | Killed to diameter .9 inch. |

the other five varieties—Hung Li, Ma Li, Pai Li, Ping Ding Li, and Ya Kuang Li—from 75 to 95 percent of the trees blighted in the tips. The extent of tip infection varied from eight inches in Pan Chen Ssu to sixty inches in Yarr Li. Pai Li gave the smallest percentage of infections and the tips in this variety blighted only from one to seventeen inches.

These varieties show much greater variation in the trunk than in the tip infections, the percentage ranging from 12.5 percent in Pai Li, the most resistant, to 100 percent in the most susceptible.

It is indeed fortunate that Pai Li, the finest flavored variety the writer found in China, has shown the lowest percentage of infected trees in this group of hybrids. Only two small trees were infected in the trunks and these were killed to a diameter of only .3 inch. The fruit is small to medium in size, with tender, juicy, delicious flesh containing few grit cells. It should prove valuable in breeding work. In this group Ya Kuang Li ranks second and Mi Li third in resistance. The former is a variety of good quality when grown in northern China, but in the dry summer climate of Southern Oregon the fruit produced is of very poor quality. Hung Li and Yarr Li are the two most widely grown varieties of northern China. In our work the former proved moderately susceptible and the latter highly susceptible in the trunks. The other varieties tested show a high degree of susceptibility. These are of strictly secondary importance in China and apparently promise nothing to the American pear industry.

## BLIGHT RESISTANCE IN MOST RESISTANT VARIETIES OF PYRUS COMMUNIS AND ITS HYBRIDS

Inoculation results obtained from the most resistant varieties of *Pyrus communis* and its hybrids are presented in Table V. These were propagated by grafting, and the trees should not be confused with seedlings of these varieties.

We have placed them in a separate group since they have shown a higher degree of resistance to blight than the other varieties belonging to this species, and some of them appear to be of special value as resistant body stocks for our commercial pears. While these are regarded as the most resistant varieties of this species, a glance at the table will indicate that none of them are immune. There is also great variation among the several varieties. The tip infections ranged from 31.2 percent in Douglas to 100 percent in Kieffer. The three varieties most resistant in the tips were Douglas with 31.2 percent, Farmingdale with 45.6 percent, and Old Home with 50 percent infection. In seven varieties; namely, Burkett, Lemon, Longworth, Orel, Serrulata No. 479, Tolstoy, and Variolosa, from 52.6 to 75 percent of the inoculations were successful. Estella and Kieffer showed 83.3 and 100 percent respectively.

The extent of tip infection was least in Douglas, Farmingdale, and Tolstoy, and greatest in Burkett, Estella, Lemon, Old Home, Orel, Surprise, and Variolosa. The extremes of infection are given and each variety shows considerable variation. In a vast majority of these cases the extent of infection was comparatively small.

The results obtained from trunk inoculations in these varieties are very important and should be carefully studied. The percentage of trunk infection varies from nothing in Farmingdale to 69.1 percent in Burkett.

TABLE V. INOCULATION RESULTS FROM MOST RESISTANT VARIETIES OF P. COMMUNIS AND ITS HYBRIDS
(Grafted trees)

| VARIETIES | Age of tree. | Number of years inoculated. | Tip inoculations |  |  |  | Trunk inoculations |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Number of dates on which inoculated. | Total number of trees inoculated in tips. | Total number of tip inoculations. | Percent of trees infected in tips. | Extent of tip infection. | Total number of trees inoculated on trunks. | Total number of trunk inoculations. | Percent of trees infected in trunks. | Percent of trees with cankers only. | Percent of trees with light trunk infections | Percent of trees with medium trunk infections. | Percent of trees with heavy trunk infections. |
|  |  |  |  |  |  | % |  |  |  | % | % | % | % | % |
| Burkett | 2-8 | 9 | 23 | 15 | 109 | 73.3 | 2 to 36 inches | 51 | 226 | 69.1 | 21.5 | 7.9 | 8.0 | 31.7 |
| Douglas | 2-5 | 7 | 18 | 16 | 48 | 31.2 | 2 to 5 inches | 43 | 211 | 65.0 | 37.2 | .0 | 4.6 | 23.2 |
| Estella | 1-7 | 9 | 19 | 18 | 84 | 83.3 | 3 to 30 inches | 57 | 250 | 17.5 | 15.8 | .0 | 1.7 | .0 |
| Farmingdale | 1-2 | 2 | 8 | 29 | 134 | 45.6 | 1 to 7 inches<br>2 trees 10 and 17 inches | 17 | 102 | .0 | .0 | .0 | .0 | .0 |
| Kieffer | 2-5 | 5 | 11 | 11 | 49 | 100.0 | 14 to 22 inches | 28 | 129 | 50.0 | 32.1 | .0 | 3.6 | 14.3 |
| Lemon | 1-7 | 6 | 17 | 34 | 154 | 61.7 | 1 to 14 inches<br>1 tree 24 inches<br>1 tree 36 inches | 41 | 173 | 26.8 | 14.6 | .0 | .0 | 12.2 |
| Longworth | 1-9 | 9 | 22 | 31 | 115 | 74.2 | 1 to 24 inches | 41 | 156 | 26.7 | 21.9 | 4.8 | .0 | .0 |
| Old Home | 1-8 | 9 | 46 | 66 | 209 | 50.0 | 2 to 30 inches | 187 | 646 | 12.2 | 8.0 | 2.6 | .0 | 1.6 |
| Orel | 1-7 | 10 | 26 | 32 | 134 | 56.2 | 1 tree 46 inches<br>1 tree 72 inches<br>2 to 36 inches<br>1 tree 54 inches | 104 | 481 | 66.4 | 12.5 | 2.9 | 1.0 | 50.0 |
| Serrulata No. 479 | 2-8 | 9 | 26 | 21 | 90 | 61.9 | 2 to 24 inches | 22 | 96 | 40.9 | 40.9 | .0 | .0 | .0 |
| Surprise | 1-7 | 9 | 37 | 31 | 119 | 77.4 | 2 to 36 inches | 168 | 774 | 63.1 | 42.3 | .0 | 3.0 | 17.2 |
| Tolstoy | 1-8 | 5 | 17 | 19 | 79 | 52.6 | 12 to 15 inches | 28 | 130 | 3.6 | 3.6 | .0 | .0 | .0 |
| Variolosa | 1-9 | 10 | 46 | 56 | 269 | 75.0 | 2 to 30 inches<br>1 tree 54 inches | 88 | 484 | 29.5 | 22.7 | 4.5 | .0 | 2.3 |

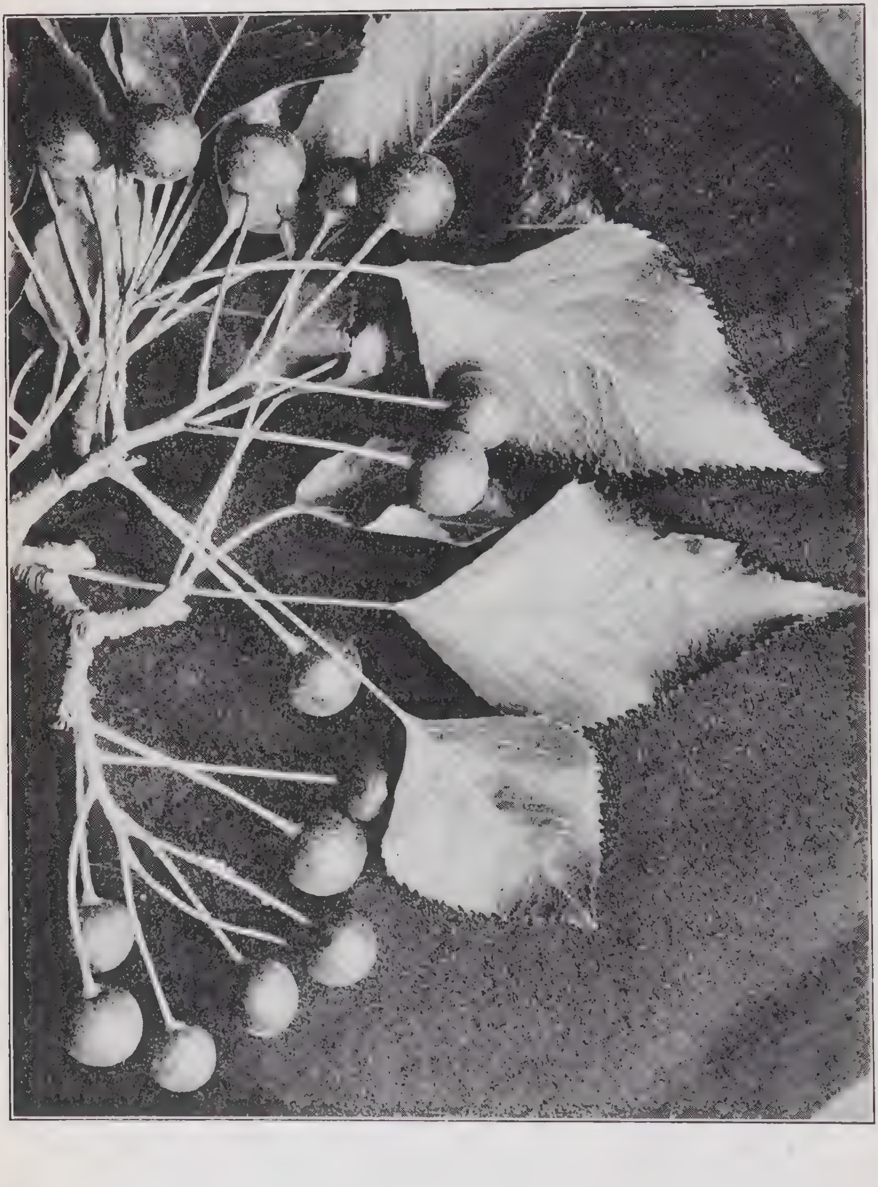

Fig. 17. Fruit and leaves of *P. betulaefolia*. (Natural size.)

The following seven varieties have shown a very high degree of resistance in the trunks: Estella, Farmingdale, Longworth, Old Home, Serrulata No. 479, Tolstoy, and Variolosa. Farmingdale has shown the highest resistance, with no infection in the trunks. This result should not be regarded as final, however, since the trunk inoculations have been confined to one season's work and to two-year-old trees. It is possible that under exceptional weather conditions the inoculations might be successful. Nevertheless, it now seems probable that this will prove very resistant, since it is the only cultivated variety of *P. communis* which has shown immunity to blight in two-year-old trunks. It has shown a remarkable degree of resistance in the tips; all the infections, with two exceptions, have been confined to the upper one to seven inches of the shoots. In one shoot the disease ran down ten and in another shoot seventeen inches. Furthermore, on the rich soils of central Illinois, where the Farmingdale originated and where blight is exceptionally

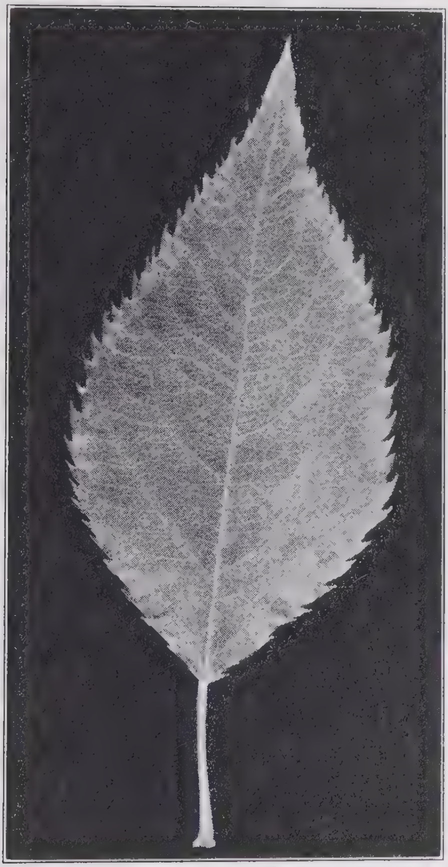

Fig. 18. Typical leaf of *P. betulaefolia.*

severe, it has shown no natural infections. Extensive inoculation work will be done with this variety during the coming years and if it continues to show an equal degree of resistance it will doubtless prove quite valuable.

Tolstoy, a hybrid between *P. communis* and *P. ovoidea,* originated by Prof. N. E. Hansen at the South Dakota Experiment Station, ranks second in resistance in this group. Only one tree, 3.6 percent, has blighted in the trunk, and these infections consisted of superficial bark cankers which quickly healed over without injuring the tree in the slightest degree. The fruit of this new variety has proved worthless in Southern Oregon, owing to its small size and poor flavor. The young trees in the nursery make a slow growth, but make a good growth when transplanted to the orchard, especially on very fertile soil. If this variety shows sufficient vigor under diverse soil conditions it may prove valuable as a stock for top-working.

In this group Old Home ranks third in resistance. While 12.2 percent of the inoculated trunks blighted, 8 percent of these trees developed only superficial bark cankers which readily healed over. In five trees, or 2.6 percent, the infections were classed as light, with less than one-third of the young trunks blighted. Three trees, or 1.6 percent, developed heavy trunk infections. Two of these trees were small, and quite young, while one was three years old, with a diameter of one and one-half inches. In the latter tree the disease did not extend to the rootstock. The trees have been repeatedly inoculated under various conditions and at different seasons of the year. The extremely small number of infections obtained during nine years' work indicates that only in very rare instances can this variety be infected in the trunk and larger wood. The fruit is of poor quality; hence this variety is of value only as a stock for top-working and possibly for breeding purposes. As a stock for top-working it seems exceptionally promising, for it is the most vigorous grower in our collection and the tree develops a sturdy framework and perfect form. This variety is a pure *P. communis* and like Farmingdale it originated in central Illinois.

While Estella has shown a slightly higher total percentage of infection than Old Home, it has shown a smaller percentage of severe trunk infection than the latter. In this variety, with the exception of one tree, all of the trunk infections have been superficial bark cankers, and in this single exception less than two-thirds of the young trunk was killed. This variety is a seedling of Kieffer, hence a cross between *P. communis* and *P. serotina.* The fruit is of very poor quality. The tree is a good grower on fertile, mellow soils, and a moderate grower on heavy clay soils. On heavy soil it is not nearly as vigorous as Old Home. It is also injured by excessive amounts of lime in the soil, and is inferior to Old Home as a stock for top-working.

Although Longworth has shown a considerably higher total percentage of trunk infections than either Old Home or Estella, it has given a smaller percentage of medium and heavy trunk infections than either of those varieties. While it shows 26.7 percent total infections, all of these except in two trees consisted of superficial bark cankers. In small two-year-old trees the trunks were killed to a diameter of one-half inch. This variety may be classed as highly resistant in the trunks, and quite vigorous, although it is not as vigorous as Old Home. The tree, however, possesses one fault: the trunk, at least in Southern Oregon, is subject to winter injury. In 1919 with a temperature of ten degrees below zero, and again in 1924 with two degrees above, considerable bark splitting occurred on the trunks. This is remarkable, since the variety originated in Iowa and is hardy there. The injury experienced here may be due to the usual mild winter weather, followed on these two occasions by exceptionally severe temperatures. It is evidently hardy in a much colder but more constant climate. It is unfortunate that it shows this weakness under local conditions; otherwise it would probably be very valuable as a blight-resistant stock. Until we have further evidence regarding its hardiness it cannot be recommended for that purpose. The fruit is of poor quality. While we have no record of the ancestry of

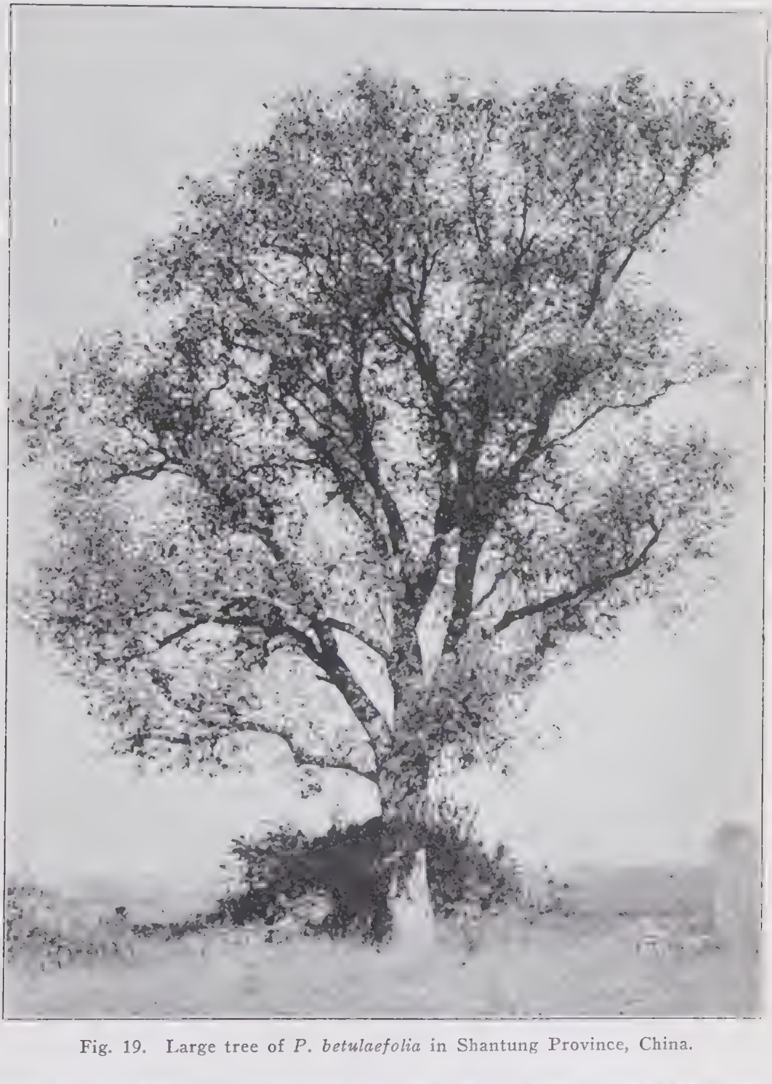

Fig. 19. Large tree of *P. betulaefolia* in Shantung Province, China.

Longworth, it is chiefly *P. communis,* but evidently is an attenuated hybrid with a small amount of Oriental blood.

Variolosa is another variety which has shown a gratifying degree of resistance to blight. While this is classed by botanists as a species, and the name as a synonym of *P. pashia,* the type which we have is unquestionably distinct from that species. It appears to be a hybrid between *P. pashia* and *P. communis* and the seedlings are variable. For the reason stated above, the writer has classed it with this group of varieties rather than with the species. Although the percentage of infected trees is 29.5 percent, the vast majority of these, 22.7 percent, developed only superficial bark cankers which did not injure the trees. Four of the young trees showed light trunk infections. Two trees, or 2.3 percent, developed heavy trunk infections. One of these was a small two-year-old tree which blighted severely. The other was a six-year-old tree with a trunk diameter of 2.4 inches and was killed to two inches above the rootstock. Why this one tree should blight severely and the other four of the same age, growing under identical conditions, thoroughly inoculated on the same dates and with the same blight culture, should remain immune, is a mystery. Furthermore, the trunk of this tree had resisted all attempts to infect it during previous years.

Five years ago we top-worked fifty trees of Variolosa with Anjou, Bosc, Bartlett, Comice, and Winter Nelis to determine whether these susceptible varieties would influence the degree of resistance of Variolosa. During the last two years the Variolosa trunks of these trees have been repeatedly inoculated and all of them have proved highly resistant. In a few instances small superficial bark cankers were produced on the young trunks, but none of these caused any material injury. Trunks of these top-worked trees proved as resistant to blight as Variolosa check trees of the same age which had not been top-worked. It is evident from these results that the resistant trunk of this variety is not rendered more susceptible to blight as a result of being top-worked with our five leading commercial blight-susceptible varieties.

In two cases the Bartlett and Bosc tops were inoculated with Pear Blight and blighted down to the Variolosa stock. In one tree the disease stopped at the union, and in the other it extended only an inch and a half below the union into the Variolosa stock. This of course is a severe test, since the Bartlett and Bosc tops are extremely susceptible, blighted vigorously above the union, and consequently millions of bacteria were massed at the union. The fact that the Variolosa framework could withstand this mass action of millions of bacteria brings out clearly its high degree of resistance.

Variolosa appears very promising as a framework stock for top-working. It is a vigorous grower, although not equal to Old Home in this respect, develops a clean, strong, well formed framework, and has proved perfectly hardy in Southern Oregon, and at the Arnold Arboretum near Boston, Mass. When Anjou, Bartlett, Bosc, Comice, and Winter Nelis are top-worked to this stock the union is smooth and strong; the scion maintains the same size as the stock below it, and the tops make a very vigorous growth.

In this group we have placed a certain type of *P. serrulata* which is designated as Serrulata No. 479. It was obtained from the Arnold Arboretum under this number and was grown from seed collected in China by Mr. E. H. Wilson. This particular type has proved very resistant, while his other types of that species have proved quite susceptible to blight at the Southern Oregon Station. Slightly more than 40 percent of the inoculations on the trunks of this type proved successful, but not a single infection extended

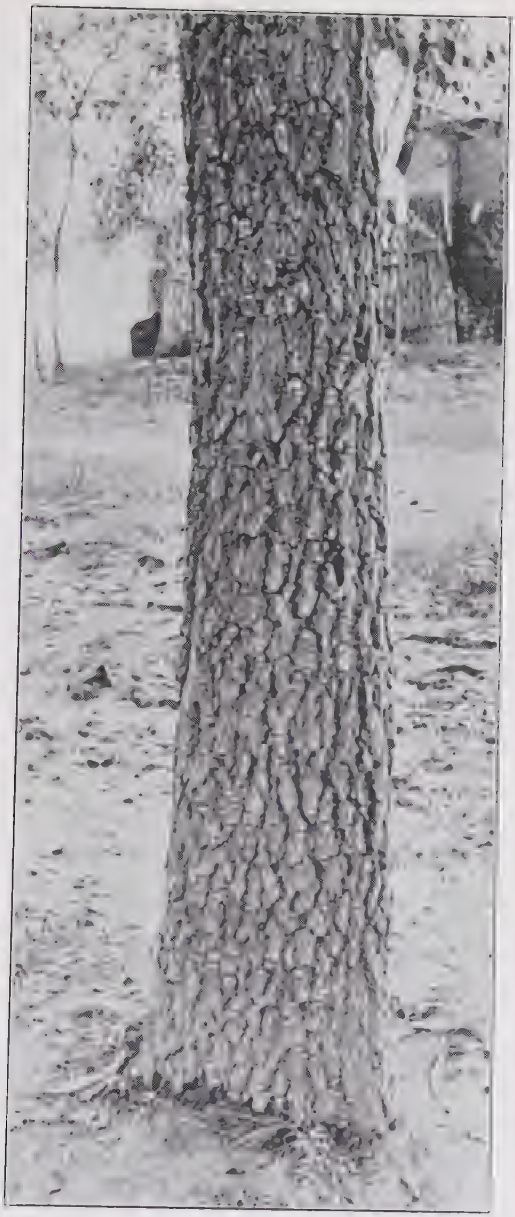

Fig. 20. Typical trunk of old tree of *P. betulaefolia.*

beyond the canker stage. These were of small size in the majority of cases, and in all cases they were confined to the outer bark and healed over quickly. For nine years the work has been conducted with trees from two to eight years old and every effort has been made to kill them, but the severest infections resulted in bark cankers only.

Although designated by the Arboretum as *P. serrulata,* this is evidently a hybrid between *P. serrulata* and *P. betulaefolia.* It produces extremely small, worthless fruit, similar to that borne by *P. betulaefolia.* The young trees are only moderate growers in the nursery, but become more vigorous with age, and in the orchard develop a good, strong framework for top-working. Serrulata No. 479 has not yet been top-worked with any of our commercial varieties, but it will be thoroughly tested for that purpose in the future. Botanically it cannot be classed in this group, but it has been placed here because of its possible value as a framework stock, for which purpose this group of varieties is most suitable.

Lemon is another variety which has shown a moderate degree of resistance, although it is not nearly as resistant as the varieties just discussed. A total of 26.8 percent of the trees were infected, but 14.6 percent of them developed only bark cankers. The heavy trunk infections amountd to 12.2 percent. This is a rather high percentage of trunk infection; at the same time, it possesses other desirable characteristics. It is a variety of *P. communis,* a native of Russia, and has proved hardy as far north as Ottawa, Canada. In cold regions it may prove hardier than any of the other resistant varieties. It is also a vigorous grower and develops a strong, well shaped framework suitable for top-working. The fruit is of poor quality.

Of the remaining five varieties, Burkett, Douglas, Orel, and Surprise have shown a high degree of resistance under natural conditions in the Mississippi Valley, a region where blight is very severe. Kieffer has for many years been known as moderately resistant to this disease. These five varieties have shown a high total percentage of infection, and also a high percentage of heavy infections.

The inoculation results obtained from Douglas, Orel, and Surprise have proved extremely interesting in one respect; namely, that these varieties appear to be far more resistant in the young shoots than in the trunks. In Douglas and Orel the total percentages of trunk infections were considerably higher than the tip infections, and in all three varieties the trunk infections usually proved far more severe than the tip infections. The vast majority of tip infections were slight, usually killing the young, vigorous shoots for a distance of only two to twelve inches, and in a very high percentage only two to six inches. On the other hand, the infections resulting from inoculations made directly into the larger and older wood of the trunks, which were from three-fourths of an inch to two inches in diameter, proved severe, particularly in Orel. At present it is impossible to explain why the disease, in the vast majority of cases, did not progress very far through the young shoots, but killed many of the trunks when injected directly into them. Evidently the young shoots, for some unknown reason, possess a factor for resistance which is either absent or not so highly developed in the older wood.

Under natural conditions blight infection usually develops first in either the young, tender wood or in the blossoms, and the fact that these varieties have remained remarkably free from severe blight injury in the Middle West is probably due to the resistance of the younger portions of the tree. It is not due to high resistance in the older wood. In this respect they differ from our well known commercial pears, in which the youngest wood usually blights most readily.

It is evident, therefore, that a variety which shows very little natural infection under field conditions is not necessarily resistant in the older wood and thus suitable as a body stock for our susceptible commercial varieties. These commercial varieties often blight readily to the stock, and if the stock is not resistant in the older wood the disease progresses into it and destroys it. Hence the great importance of artificially inoculating a promising variety in the larger and older wood before recommending it as a blight-resistant body stock. The results from tip inoculations alone are not sufficient. For example, Orel has proved much more resistant in the young shoots than either Estella, Longworth, or Variolosa, but its susceptibility in the trunks is far more marked than in these latter varieties.

## BLIGHT RESISTANCE IN SUSCEPTIBLE VARIETIES OF P. COMMUNIS AND ITS HYBRIDS

Table VI gives the inoculation results obtained from the more susceptible American and European varieties. This list consists of *P. communis* varieties with the exception of Abraham, Conkleton, Gogol, and Siebold, which are *P. communis* hybrids, and Pineapple, which is a Chinese variety of uncertain origin, probably *P. serotina.*

It is evident from the table that the vast majority of varieties in this list are so highly susceptible to blight that no discussion of them is necessary. The work with some of them has been too limited to make the results conclusive. These results are included here because they are indicative, and as a matter of record.

The following varieties in this group have shown far greater resistance than the others: Conkleton, Durand, Early Harvest, German Sugar, Hafraths Birne, Horns Winter, Miller, Pineapple, Siebold, Snyder, Stout, Warner, and Wilkinson. In fact, Conkleton, Horns Winter, and Pineapple have shown a very high degree of resistance, and if they possessed other desirable characteristics would have been included in Table V. The fruit of these three varieties is worthless in Southern Oregon. The trees are slow growers on our heavy soils, and Pineapple is subject to winter injury during our coldest winters.

The work with two of the varieties in this list, Lincoln and Snyder, has not been sufficient to justify conclusions. While these two varieties blight readily in the young wood when inoculated, the fact that natural infections on these in the variety orchard have been few and confined to small wood indicates that the older wood is probably resistant. The inoculation work with these varieties will therefore be continued.

TABLE VI. INOCULATION RESULTS FROM SUSCEPTIBLE P. COMMUNIS VARIETIES AND HYBRIDS
(Grafted trees)

| VARIETIES | | | Tip inoculations | | | | | Trunk inoculations | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Age of trees. | Number of years inoculated. | Number of dates on which inoculated. | Total number of trees inoculated in tips. | Total number of tip inoculations. | Percent of trees infected in tips. | Extent of tip infection. | Number of trees inoculated on trunks. | Total number of trunk inoculations. | Percent of trees infected in trunks. | Percent of trees with light trunk infection. | Percent of trees with medium trunk infection. | Percent of trees with heavy trunk infection. | |
| | | | | | | % | | | | % | % | % | % | |
| Abraham | 2-3 | 3 | 3 | 2 | 4 | 100.0 | 36 to 38 inches | 6 | 12 | 66.7 | 16.7 | ...... | 50.0 | |
| Alberta | 1-5 | 2 | 3 | 7 | 13 | 100.0 | Killed | 2 | 4 | 100.0 | ...... | ...... | 100.0 | 2 trees killed |
| Alkire | 2-3 | 2 | 2 | ...... | ...... | ...... | | 4 | 14 | 100.0 | ...... | ...... | 100.0 | 4 trees killed |
| Amanlis Panache | 5 | 1 | 3 | 1 | 5 | 100.0 | 30 to 36 inches | 3 | 21 | 33.3 | ...... | ...... | 33.3 | 1 tree killed |
| Ayer | 2 | 2 | 2 | 1 | 5 | 100.0 | 16 inches | 2 | 8 | 100.0 | ...... | ...... | 100.0 | 2 trees killed |
| Beaumont | 3 | 1 | 1 | ...... | ...... | ...... | | 1 | 3 | 100.0 | ...... | ...... | 100.0 | 1 tree killed |
| Besi de La Motte | 1-5 | 5 | 7 | 6 | 8 | 100.0 | 4 inches to trunk | 14 | 42 | 92.8 | 35.7 | 7.1 | 50.0 | 7 trees killed |
| Bessimianka | 1-5 | 5 | 16 | 13 | 25 | 100.0 | 16 inches to stock | 26 | 76 | 100.0 | 3.8 | 3.8 | 92.3 | 24 trees killed |
| Beurre Gris | 3 | 1 | 1 | ...... | ...... | ...... | | 1 | 3 | 100.0 | ...... | ...... | 100.0 | 1 tree killed |
| Beurre Oudinot | 1-6 | 2 | 2 | 3 | 3 | 100.0 | Killed | 4 | 8 | 100.0 | ...... | ...... | 100.0 | 4 trees killed |
| Bilboa | 1 | 1 | 1 | 2 | 2 | 100.0 | Killed | ...... | ...... | ...... | ...... | ...... | ...... | |
| Blanque Precoce | 4 | 1 | 1 | ...... | ...... | ...... | | 2 | 6 | 100.0 | ...... | ...... | 100.0 | 2 trees killed |
| Blickling | 2-6 | 2 | 3 | 2 | 5 | 100.0 | 24 inches | 2 | 6 | 100.0 | ...... | ...... | 100.0 | 2 trees killed |
| Bonne de Malines | 6 | 1 | 1 | ...... | ...... | ...... | | 1 | 3 | 100.0 | ...... | ...... | 100.0 | 1 tree killed |
| Bordeaux | 3-4 | 2 | 2 | ...... | ...... | ...... | | 12 | 48 | 100.0 | ...... | ...... | 100.0 | 12 trees killed |
| Citron de Carmes | 1-3 | 3 | 4 | 7 | 15 | 100.0 | 14 inches to trunk | 3 | 9 | 100.0 | 66.7 | ...... | 33.3 | 1 tree killed |
| Comte de Paris | 5 | 1 | 1 | ...... | ...... | ...... | | 1 | 1 | 100.0 | ...... | ...... | 100.0 | 1 tree killed |
| Conkleton | 1-8 | 8 | 17 | 4 | 56 | 100.0 | 2 to 28 inches | 4 | 95 | 50.0 | 25.0 | 25.0 | 0.0 | Outer bark canker |
| Crocker Bartlett | 1-2 | 2 | 2 | 5 | 11 | 80.0 | Killed to stock | ...... | ...... | ...... | ...... | ...... | ...... | |
| Diel | 2 | 1 | 1 | ...... | ...... | ...... | | 1 | 3 | 100.0 | ...... | ...... | 100.0 | 1 tree killed |
| Duchess Precoce | 1 | 1 | 1 | 3 | 3 | 100.0 | 10 to 27 inches | ...... | ...... | ...... | ...... | ...... | ...... | |
| Durand | 2-5 | 5 | 6 | 2 | 12 | 100.0 | 10 inches | 7 | 27 | 57.1 | 42.8 | ...... | 14.3 | |
| Early Harvest | 1-7 | 7 | 13 | 16 | 57 | 100.0 | 2 to 60 inches | 34 | 108 | 47.0 | 29.4 | ...... | 17.6 | 6 trees killed |
| Effie Holt | 1-5 | 6 | 8 | 6 | 28 | 83.3 | 6 to 48 inches | 11 | 32 | 72.7 | ...... | ...... | 72.7 | 8 trees killed |
| Espargne | 2 | 1 | 1 | 3 | 9 | 100.0 | Killed. | ...... | ...... | ...... | ...... | ...... | ...... | |
| Fauke Tivule | 3-4 | 3 | 3 | ...... | ...... | ...... | | 10 | 30 | 100.0 | ...... | ...... | 100.0 | 10 trees killed |
| Favorita | 1-2 | 2 | 2 | 4 | 4 | 100.0 | 10 inches to stock | ...... | ...... | ...... | ...... | ...... | ...... | |
| Figue | 5 | 1 | 1 | ...... | ...... | ...... | | 1 | 3 | 100.0 | ...... | ...... | 100.0 | 1 tree killed |
| Fluke | 2-6 | 5 | 7 | 6 | 28 | 83.3 | 4 to 24 inches | 13 | 42 | 100.0 | 23.0 | ...... | 76.9 | 6 trees killed |
| Fontenay | 1 | 1 | 1 | 3 | 3 | 100.0 | Killed | ...... | ...... | ...... | ...... | ...... | ...... | |
| Forelle | 2-5 | 6 | 22 | 22 | 76 | 100.0 | Killed | 20 | 70 | 100.0 | ...... | ...... | ...... | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Girard | 5 | 1 | 1 | | | | | 1 | 3 | 100.0 | | | 100.0 | 1 tree killed |
| Gogol | 4-6 | 3 | 7 | 4 | 34 | 50.0 | 5 to 12 inches | 4 | 64 | 75.0 | 25.0 | | 50.0 | |
| Gold Nugget | 1-4 | 4 | 6 | 2 | 10 | 100.0 | Killed | 5 | 25 | 100.0 | 20.0 | | 80.0 | 2 trees killed |
| Goubault | 5 | 1 | 1 | | | | | 1 | 3 | 100.0 | | | 100.0 | 1 tree killed |
| Graslin | 5 | 1 | 1 | | | | | 2 | 6 | 100.0 | | | 100.0 | 2 trees killed |
| Guyot | 2-4 | 4 | 4 | 1 | 3 | 100.0 | Killed to trunk | 5 | 15 | 100.0 | | | 100.0 | 5 trees killed |
| Hafrath's Birne | 3-6 | 4 | 6 | 3 | 15 | 100.0 | Killed to trunk | 22 | 79 | 45.4 | 9.1 | | 36.4 | 5 trees killed |
| Hardy | 2-6 | 3 | 6 | 8 | 20 | 87.5 | 3 to 48 inches | 6 | 39 | 100.0 | | | 100.0 | 6 trees killed |
| Heyst | 1 | 1 | 1 | 5 | 5 | 100.0 | Killed | | | | | | | |
| Horns Winter | 1-7 | 7 | 15 | 9 | 29 | 66.7 | 9 to 46 inches | 26 | 71 | 26.9 | 7.7 | 7.7 | 11.5 | 1 tree killed |
| Hourdequin | 3-4 | 2 | 2 | | | | | 2 | 6 | 100.0 | | | 100.0 | 2 trees killed |
| Idaho | 3-5 | 2 | 2 | 2 | 6 | 100.0 | Killed | 3 | 9 | 100.0 | | | 100.0 | 3 trees killed |
| Joan de Arc | 1-4 | 3 | 3 | 5 | 5 | 100.0 | Killed | 7 | 21 | 100.0 | | | 100.0 | 7 trees killed |
| Kincaid | 3 | 1 | 1 | | | | | 1 | 3 | 100.0 | | | 100.0 | 1 tree killed |
| Koonce | 3-4 | 1 | 3 | 3 | 7 | 100.0 | 1 inch to ground | | | | | | | |
| Krull | 2 | 2 | 3 | 2 | 5 | 100.0 | 3 to 24 inches | 2 | 11 | 100.0 | | | 100.0 | |
| Kurskya | 1-5 | 5 | 8 | 6 | 12 | 100.0 | 12 to 36 inches | 20 | 70 | 90.0 | 5.0 | | 85.0 | 17 trees killed |
| Lincoln | 1-2 | 3 | 3 | 7 | 17 | 100.0 | 1 inch into trunk to diameter .7 inch | | | | | | | |
| Louise Bonne | 2 | 1 | 1 | 3 | 9 | 100.0 | Killed | | | | | | | |
| Lucy Duke | 2-3 | 3 | 4 | | | | | 10 | 22 | 100.0 | | | 100.0 | 3 trees killed |
| Madame Chervet | 6 | 1 | 1 | | | | | 1 | 3 | 100.0 | | | 100.0 | 1 tree killed |
| Margaret | 2 | 1 | 1 | 3 | 9 | 100.0 | Killed | | | | | | | |
| Mendel | 1-2 | 2 | 4 | 10 | 30 | 77.7 | 12 to 22 inches | 4 | 24 | 100.0 | | | 100.0 | 3 trees killed |
| Miller | 1-5 | 5 | 8 | 5 | 17 | 20.0 | 5 to 34 inches. | 12 | 36 | 25.0 | 16.7 | | 8.3 | 1 tree killed |
| Mormon | 1-5 | 5 | 8 | 8 | 24 | 100.0 | 36 to 72 inches | 9 | 25 | 77.8 | | | 77.8 | 1 tree killed |
| Olivier | 5 | 1 | 1 | | | | | 1 | 3 | 100.0 | | | 100.0 | 1 tree killed |
| Pineapple | 1-4 | 6 | 10 | 16 | 19 | 87.5 | 6 to 30 inches | 12 | 44 | 8.3 | 8.3 | | | |
| Pound | 1-2 | 2 | 2 | 5 | 11 | 60.0 | Killed to ground | | | | | | | |
| Pratt | 4 | 1 | 1 | | | | | 4 | 8 | 100.0 | | | 100.0 | 4 trees killed |
| Precoce de Angiers | 5 | 1 | 1 | | | | | 1 | 3 | 100.0 | | | 100.0 | 1 tree killed |
| President Drouard | 1-3 | 3 | 4 | 7 | 15 | 100.0 | Killed | 4 | 20 | 100.0 | | | 100.0 | 4 trees killed |
| President Roosevelt | 3-4 | 3 | 3 | | | | | 13 | 36 | 100.0 | | | 100.0 | 13 trees killed |
| Rossney | 1-5 | 4 | 5 | 5 | 5 | 100.0 | Killed | 9 | 27 | 100.0 | | | 100.0 | 9 trees killed |
| Santa Claus | 2 | 1 | 1 | 5 | 5 | 100.0 | Killed | | | | | | | |
| Seckel | 2-4 | 4 | 6 | 5 | 19 | 100.0 | 24 inches to trunk | 8 | 30 | 100.0 | 12.5 | | 87.5 | 4 trees killed |
| Sheldon | 1-2 | 2 | 2 | 4 | 8 | 75.0 | Killed | | | | | | | |
| Siebold | 1-5 | 4 | 7 | 4 | 10 | 100.0 | 2 to 26 inches | 26 | 96 | 34.6 | | | 34.6 | |
| Smyth | 2-5 | 3 | 4 | 2 | 5 | 100.0 | 6 to 36 inches | 4 | 14 | 100.0 | 50.0 | | 50.0 | |
| Snyder | 1-2 | 2 | 2 | 5 | 11 | 80.0 | 6 to 16 inches | | | | | | | |
| Stout | 2-3 | 3 | 5 | 2 | 8 | 100.0 | 12 inches to trunk | 4 | 12 | 25.0 | | | 25.0 | 1 tree killed |
| Superb | 2-5 | 3 | 4 | 3 | 6 | 100.0 | 10 to 24 inches | 3 | 14 | 100.0 | | | 100.0 | 1 tree killed |
| Tedrow Beauty | 2-4 | 2 | 4 | | | | | 4 | 16 | 75.0 | | | 75.0 | 3 trees killed |
| Tongres | 1-5 | 4 | 6 | 5 | 5 | 100.0 | Killed | 17 | 55 | 100.0 | | | 100.0 | 17 trees killed |
| Triomphe de Dives | 5 | 1 | 1 | | | | | 1 | 3 | 100.0 | | | 100.0 | 1 tree killed |
| Tyson | 1-3 | 3 | 3 | 5 | 11 | 40.0 | 14 inches to trunk | 1 | 3 | 100.0 | | | 100.0 | 1 tree killed |
| Vermont Beauty | 2 | 1 | 1 | 1 | 5 | 100.0 | 30 to 48 inches | 1 | 1 | 100.0 | | 100.0 | | |
| Vicar of Wakefield | 2 | 1 | 1 | 3 | 9 | 100.0 | Killed | | | | | | | |
| Vienna | 3-6 | 2 | 2 | | | | | 2 | 6 | 100.0 | | | 100.0 | 1 tree killed |
| Warner | 2-5 | 5 | 9 | 4 | 16 | 100.0 | 3 to 36 inches | 15 | 46 | 53.3 | 13.3 | 13.3 | 26.7 | 2 trees killed |
| Wilkinson | 1-5 | 4 | 8 | 7 | 17 | 42.8 | 8 inches to trunks | 12 | 38 | 41.7 | 8.3 | | 33.3 | 3 trees killed |
| Zink | 1 | 1 | 1 | 5 | 5 | 100.0 | 2 to 16 inches | | | | | | | |

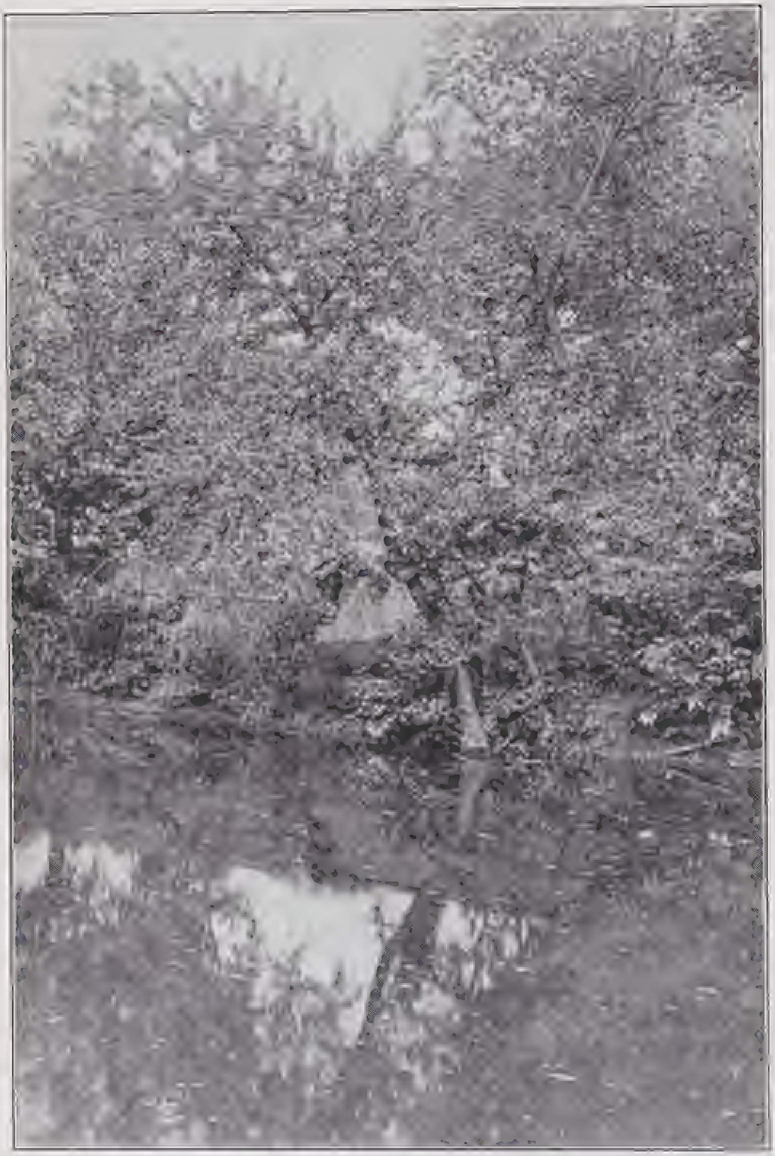

Fig 21. Tree of *P. betulaefolia* growing at edge of pond in northern China.

## NATURAL INFECTIONS IN THE VARIETY ORCHARD

Table VII gives a record of the natural infections which have occurred in our extensive variety collection. Since these trees have been infected by natural agencies, this being a matter of chance, the results are not strictly comparable. As the several varieties, however, have received similar treatment otherwise and are confined to a comparatively small orchard in which blight has been very prevalent every year, the results are of considerable value. Furthermore, since a very large percentage of these trees have blighted seriously and many of them have been killed, the results obtained with these particular varieties are probably as valuable as they would be if the trees had been artificially inoculated. Since most of these varieties were imported directly from Europe, where blight is unknown, and there is no record in this country regarding their susceptibility or resistance, the results are undoubtedly well worth recording.

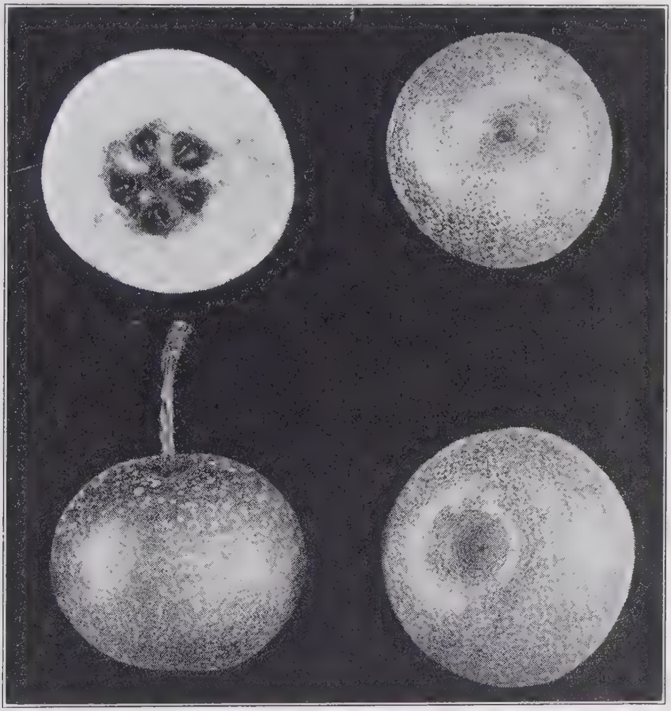

Fig. 22. Fruit of the Japanese Sand Pear *(P. serotina)*. Note absence of calyx.

The variety orchard is only twelve years old, located on fertile river bottom soil, and has received clean cultivation and irrigation. One hundred and thirty-two varieties or 34 percent of all those in the orchard, have been killed. In two hundred and fifty-two, or 65 percent of the varieties, wood two inches or more in diameter has blighted, three hundred and seventy-seven varieties, or 97 percent, have shown infection. Eleven varieties, or less than 3 percent, have not blighted. Of these, five varieties, Ayer, Chieh Li, Douglas, Horns Winter, and Longworth, are not immune, as shown by our inoculation results.

Undoubtedly a much larger percentage of the varieties would have been killed if the infections had been left to run their course. The orchard was diligently patrolled during the blight season, and all infections taken out of the trees; most of them before the disease stopped running. Without doubt many more varieties would have been killed if such care had not been exercised. Future reports on this orchard will unquestionably add many varieties to the list of those killed.

Our commercial orchard includes the six leading varieties grown in Southern Oregon. We have lost some trees of each of these varieties. The losses have been greatest in Bosc and Howell. Bartlett and Comice rank second in susceptibility. Anjou and Winter Nelis have suffered least.

TABLE VII. RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

| Variety | Age of trees | Number of years blighted | Number of infections | Diameter of largest wood killed *in.* | |
|---|---|---|---|---|---|
| Abraham | 11 | 5 | 50 | 4 | |
| Ah Mon Dieu | 12 | 4 | 9 | 1½ | |
| Airoles (Leclerc) | 10 | 6 | 17 | 1½ | |
| Alamo | 8 | 2 | 22 | 5 | Tree killed |
| Alexandre Lucas | 12 | 5 | 16 | 4 | |
| Alexandre III | 11 | 2 | 6 | 3½ | |
| Alliance Franco Russe | 11 | 1 | 1 | ½ | |
| Alphand | 11 | 2 | 8 | 1½ | |
| Amanlis Panache | 10 | 3 | 15 | 3 | |
| Amelie Baltet | 11 | 0 | 0 | .... | |
| Ananas du Perche | 11 | 3 | 4 | 3¼ | |
| Andusson | 10 | 1 | 7 | .... | Tree killed |
| Andre Desports | 12 | 2 | 26 | 4 | |
| Andrews | 10 | 2 | 10 | 2¾ | |
| Angleterre | 12 | 3 | 24 | 4 | |
| Angouleme | 11 | 3 | 8 | 8 | Tree killed |
| Anne de Bretagne | 8 | 1 | 7 | .... | Tree killed |
| Archangel | 12 | 4 | 42 | 4 | |
| Arenberg Colmar | 9 | 2 | 13 | 7 | Tree killed |
| Artois | 8 | 1 | 9 | 6 | Tree killed |
| Assomption | 9 | 2 | 50 | 5 | Tree killed |
| Avocat Tonnellier | 11 | 4 | 17 | 3 | |
| Ayer | 9 | 0 | 0 | 0 | |
| Bachelier | 11 | 5 | 26 | 5 | |
| Bailey | 11 | 4 | 23 | 1½ | |
| Barillet | 12 | 3 | 13 | 3 | |
| Baronne Leroy | 12 | 3 | 8 | 1¼ | |
| Bastie | 12 | 3 | 17 | 4⅛ | |
| Baudry | 10 | 3 | 38 | 6½ | Tree killed |
| Beaumont | 9 | 2 | 3 | 3 | Tree killed |
| Beauty | 10 | 3 | 6 | 2 | |
| Belle de Beaufort | 11 | 2 | 5 | 1½ | |
| Belle de Beugny | 11 | 4 | 14 | 1½ | |
| Belle de Julliet | 12 | 4 | 15 | 1¾ | |
| Belle de Lesquin | 9 | 3 | 12 | 3 | Tree killed |
| Belle de Limoges | 9 | 2 | 12 | 4 | Tree killed |
| Belle de Picarde | 11 | 3 | 18 | 1 | |
| Benoist | 10 | 3 | 11 | 1¼ | |
| Bergamote Arsene Sannier | 12 | 5 | 55 | 2½ | |
| Bergamote de Automne | 12 | 4 | 17 | 2½ | |
| Bergamote d' Esperen | 9 | 2 | 2 | 5 | Tree killed |
| Bergamote d' Ete | 11 | 2 | 18 | 1½ | |
| Bergamote Herault | 11 | 3 | 18 | 7¼ | Tree killed |

TABLE VII (Continued). RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

| Variety | Age of trees | Number of years blighted | Number of infections | Diameter of largest wood killed | |
|---|---|---|---|---|---|
| | | | | *in.* | |
| Bergamote Nanot | 11 | 4 | 24 | 2½ | |
| Bergamote Rene | 9 | 1 | 8 | 2½ | |
| Bergamote Sageret | 11 | 3 | 11 | 2 | |
| Besi de Chaumontel | 8 | 2 | 5 | .... | Tree killed |
| Bessimianka | 6 | 1 | 6 | 5 | Tree killed |
| Beurre Gris | 9 | 2 | 12 | 5½ | Tree killed |
| Blanquet (Longue) | 11 | 4 | 95 | 8 | Tree killed |
| Blanquet Precoce | 11 | 2 | 19 | 3 | |
| Blickling | 8 | 1 | 1 | 4 | Tree killed |
| Blondet | 11 | 4 | 20 | 1¾ | |
| Bloodgood | 12 | 5 | 33 | 3½ | |
| Boisselot | 11 | 3 | 8 | 7½ | Tree killed |
| Bollwiller | 10 | 3 | 14 | 1½ | |
| Bon Chretien Bonnamour | 11 | 4 | 22 | 1¼ | |
| Bon Chretien de Vermont | 11 | 4 | 47 | 2½ | |
| Bonnefond | 12 | 3 | 15 | 1 | |
| Bonneserre | 11 | 2 | 24 | 3 | |
| Bordeaux | 11 | 4 | 10 | 2 | |
| Bordillon | 11 | 4 | 11 | 2½ | |
| Bouldieu | 12 | 4 | 30 | 7 | Tree killed |
| Boussock | 12 | 4 | 63 | 5 | Tree killed |
| Brabant | 11 | 4 | 22 | 7 | Tree killed |
| Brettonneau | 6 | 1 | 2 | 4 | Tree killed |
| Briffaut | 11 | 3 | 24 | 1¾ | |
| Brissac | 12 | 4 | 10 | 1⅛ | |
| Burkett | 11 | 3 | 11 | 1½ | |
| Caen | 6 | 1 | 2 | 3½ | Tree killed |
| Caissoy D'Hiver | 12 | 4 | 26 | 1½ | |
| Canrobert | 12 | 4 | 28 | 2 | |
| Carnot | 11 | 3 | 12 | 2½ | |
| Capiaumont | 11 | 2 | 22 | 2½ | |
| Catillac | 10 | 2 | 12 | 7 | Tree killed |
| Chandy | 11 | 1 | 3 | ¾ | |
| Chantenay | 9 | 2 | 15 | 6 | Tree killed |
| Chasseurs | 12 | 2 | 3 | ½ | |
| Chieh Li | 7 | 0 | 0 | .... | |
| Choisnard | 8 | 1 | 3 | 9 | Tree killed |
| Cincincis | 9 | 0 | 0 | .... | |
| Clairgeau | 5 | 2 | 15 | 4 | Tree killed |
| Cognee | 12 | 5 | 34 | 3 | |
| Colmar | 11 | 4 | 29 | 5 | Tree killed |
| Colmar de Mars | 11 | 2 | 8 | 3 | |
| Colonel Marchand | 12 | 5 | 18 | 1½ | |
| Columbia | 11 | 2 | 10 | 1¼ | |
| Comtesse de Paris | 9 | 2 | 9 | .... | Tree killed |
| Conkleton | 11 | 3 | 33 | 1 | |
| Corneau | 11 | 3 | 11 | 2 | |
| Cornelis | 11 | 4 | 9 | 5 | |
| Craonnaise | 8 | 1 | 8 | 5 | Tree killed |
| Crassane | 10 | 3 | 8 | 6½ | Tree killed |
| Crocker Bartlett | 9 | 2 | 5 | 8 | Tree killed |
| Dalbret | 12 | 5 | 29 | 2 | |
| Dana Hovey | 8 | 2 | 6 | 5 | Tree killed |
| Defais | 10 | 2 | 19 | 6½ | Tree killed |
| De Lacroix | 12 | 4 | 11 | 1½ | |
| Delices d'Avril | 11 | 3 | 21 | 3½ | |
| Delfosse | 12 | 4 | 20 | 2 | |
| Derouineau | 11 | 1 | 3 | ½ | |
| Desportes | 12 | 4 | 16 | 1¾ | |
| Diel | 12 | 4 | 41 | 3 | |
| Dillen | 10 | 2 | 24 | 6½ | Tree killed |
| Directeur Hardy | 11 | 4 | 20 | 1½ | |
| Directeur Tisserand | 8 | 1 | 3 | .... | Tree killed |
| Dixie | 8 | 2 | 3 | ½ | |
| Docteur Joubert | 11 | 3 | 24 | 3½ | |
| Dorset | 11 | 4 | 78 | 4 | |

TABLE VII (Continued). RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

| Variety | Age of trees | Number of years blighted | Number of infections | Diameter of largest wood killed | |
|---|---|---|---|---|---|
| | | | | *in.* | |
| Douglas | 8 | 0 | 0 | ---- | |
| Douillard | 11 | 4 | 21 | 1½ | |
| Doyenne Defais | 11 | 3 | 16 | 2 | |
| Doyenne d'Hiver | 12 | 3 | 20 | 2½ | |
| Doyenne de la Grifferaye | 11 | 2 | 9 | ½ | |
| Doyenne Georges Boucher | 11 | 2 | 3 | ¾ | |
| Duchesse Anne | 6 | 1 | 7 | 3 | Tree killed |
| Duchesse Bronzee | 11 | 1 | 2 | ¼ | |
| Dumont | 9 | 2 | 3 | 5 | Tree killed |
| Durand | 7 | 3 | 38 | 1 | |
| Easter Bergamote | 11 | 2 | 17 | 1½ | |
| Easter Beurre | 9 | 2 | 8 | 6½ | Tree killed |
| Early Green Sugar | 10 | 2 | 3 | 2 | |
| Early Harvest | 10 | 3 | 4 | 1 | |
| Ecully | 9 | 1 | 1 | 1¼ | |
| Effie Holt | 10 | 2 | 6 | 7 | Tree killed |
| Elenore Liefmans | 11 | 4 | 5 | 1½ | |
| Ernest | 5 | 1 | 1 | ---- | Tree killed |
| Espargne (de) | 11 | 3 | 15 | 6 | |
| Estella | 10 | 4 | 6 | ½ | |
| Eva Baltet | 11 | 2 | 4 | ½ | |
| Ezee | 12 | 4 | 7 | 1 | |
| Fame | 10 | 3 | 3 | 7 | Tree killed |
| Fauke Tivule | 8 | 1 | 6 | 2½ | |
| Favorita | 8 | 1 | 1 | ¾ | |
| Favorite Joanon | 11 | 2 | 8 | 1¼ | |
| Felix Sahut | 11 | 3 | 23 | 2¼ | |
| Ferron | 11 | 3 | 13 | 2 | |
| Fideline | 12 | 3 | 15 | 7 | Tree killed |
| Figue | 12 | 1 | 1 | ½ | |
| Flemish Beauty | 11 | 3 | 29 | 2½ | |
| Flou Aine | 9 | 2 | 13 | 6 | Tree killed |
| Forelle | 7 | 2 | 30 | 4 | Tree killed |
| Fortunee | 12 | 4 | 11 | 1¾ | |
| Fougiere | 9 | 3 | 19 | 3 | Tree killed |
| Fouqueray | 11 | 3 | 15 | 1½ | |
| Fox | 12 | 5 | 30 | 1½ | |
| Francois Coppee | 12 | 4 | 12 | 1⅛ | |
| Fred Clapp | 11 | 4 | 24 | 2½ | |
| Fulvie | 6 | 1 | 7 | 2½ | Tree killed |
| Gantoise | 6 | 1 | 3 | 3½ | Tree killed |
| Garber | 9 | 1 | 1 | ½ | |
| General de Villebois | 10 | 2 | 2 | 4 | Tree killed |
| General de Villebois Mareuil | 10 | 4 | 16 | 2½ | |
| General Galliene | 12 | 3 | 10 | 1 | |
| Georges d'Amboise | 11 | 3 | 13 | 2½ | |
| German Sugar | 11 | 3 | 9 | 1 | |
| Ghelin | 10 | 3 | 3 | 5 | Tree killed |
| Ghislain | 12 | 3 | 22 | 3 | |
| Giffard | 11 | 2 | 24 | 3½ | |
| Gilogil | 9 | 2 | 26 | 7 | Tree killed |
| Glou Morceau | 8 | 2 | 15 | 5 | Tree killed |
| Gold Nugget | 7 | 3 | 4 | 6½ | Tree killed |
| Goubault | 9 | 2 | 2 | 3½ | Tree killed |
| Goubault (Doy) | 12 | 2 | 2 | ½ | |
| Gratioli | 8 | 1 | 3 | 4 | Tree killed |
| Gray Doyenne | 12 | 3 | 6 | 1 | |
| Green Sweet | 12 | 3 | 4 | ¾ | |
| Griesa No. 1 | 8 | 3 | 6 | 1¼ | |
| Grosse Louise | 11 | 1 | 1 | 1 | |
| Guillard | 12 | 1 | 4 | 1 | |
| Guyot | 11 | 2 | 14 | 1 | |
| Hampden | 12 | 3 | 16 | 7 | Tree killed |
| Hardempont de Automne | 8 | 2 | 10 | 5 | Tree killed |
| Hardempont (Ang) | 11 | 2 | 17 | 2½ | |

TABLE VII (Continued). RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

| Variety | Age of trees | Number of years blighted | Number of infections | Diameter of largest wood killed | |
|---|---|---|---|---|---|
| | | | | *in.* | |
| Hardy | 12 | 4 | 34 | 10 | Tree killed |
| Harvard | 9 | 2 | 15 | 5¼ | Tree killed |
| Hawaii | 8 | 0 | 0 | ---- | |
| Hebe | 11 | 4 | 2 | ¾ | |
| Heimbourg | 10 | 1 | 2 | 2½ | Tree killed |
| Helene | 11 | 2 | 9 | 2½ | |
| Henri Desportes | 12 | 5 | 37 | 2 | |
| Herard | 12 | 2 | 12 | 1 | |
| Heri | 12 | 5 | 19 | 2½ | |
| Horn's Winter | 7 | 0 | 0 | ---- | |
| Hospice D'Angers | 11 | 3 | 4 | 1½ | |
| Hourdequin | 10 | 4 | 49 | 6¼ | Tree killed |
| Hutin | 12 | 5 | 26 | 3 | |
| | | | | | |
| Idaho | 5 | 1 | 1 | 3 | Tree killed |
| Invalides | 9 | 2 | 8 | 3½ | Tree killed |
| | | | | | |
| Jaminette | 11 | 3 | 9 | 1¼ | |
| Jodigne (Delices) | 12 | 3 | 20 | 7¼ | Tree killed |
| Joigneaux | 8 | 1 | 9 | 6 | Tree killed |
| Joyau d'Aout | 11 | 4 | 30 | 3 | |
| Joyau de September | 12 | 2 | 15 | 1½ | |
| Juteuse de Aout | 11 | 3 | 19 | 7 | Tree killed |
| | | | | | |
| Kennedy | 12 | 6 | 56 | 4 | |
| Kieffer | 8 | 1 | 2 | ½ | |
| King Karl | 12 | 3 | 12 | 1⅛ | |
| | | | | | |
| Lady Clapp | 11 | 3 | 43 | 3 | Tree killed |
| La France | 12 | 3 | 59 | 3 | |
| Lambertye | 12 | 2 | 3 | 1 | |
| Lambre (Alex) | 11 | 5 | 9 | 1 | |
| Lameriere | 11 | 3 | 9 | 1¾ | |
| Lamoriciere | 9 | 4 | 23 | 3 | |
| La Motte | 10 | 3 | 19 | 2½ | |
| Laval | 8 | 1 | 1 | 6 | Tree killed |
| La Vientienne | 12 | 0 | 0 | ---- | |
| Lawrence | 12 | 3 | 20 | 2 | |
| Le Brun | 11 | 3 | 27 | 4 | |
| Leclerc (Angelique) | 12 | 5 | 19 | 2 | |
| Le Clerc (Van Mons) | 9 | 1 | 2 | 1 | |
| Le Conte | 10 | 3 | 17 | 2 | |
| Ledeberg | 9 | 1 | 1 | ½ | |
| Lelieur (Comte) | 12 | 1 | 3 | 1 | |
| Leopold I | 10 | 2 | 16 | 3 | Tree killed |
| Leroux | 11 | 3 | 20 | 2 | |
| Leroy | 12 | 4 | 61 | 1¼ | |
| Levavasseur | 12 | 3 | 23 | 3 | Tree killed |
| Lincoln | 12 | 2 | 4 | ¾ | |
| Lincolner | 12 | 3 | 12 | 2½ | |
| Lindauer | 8 | 1 | 3 | 6 | Tree killed |
| Little Blanquet | 11 | 1 | 1 | ½ | |
| Livre | 11 | 4 | 22 | 8 | Tree killed |
| Long Green | 10 | 3 | 38 | 4 | |
| Longworth | 5 | 0 | 0 | ---- | |
| Louise Bonne | 11 | 1 | 30 | 3 | |
| Louis Pasteur | 11 | 5 | 15 | 1¾ | |
| Louvenjal | 10 | 2 | 7 | 4 | Tree killed |
| Lowe | 11 | 3 | 39 | 5 | |
| Lucien Chaure | 8 | 2 | 23 | 5 | Tree killed |
| Lucrative | 12 | 4 | 8 | 5½ | Tree killed |
| Lucy Duke | 9 | 3 | 8 | 5¾ | Tree killed |
| Luizet | 8 | 2 | 14 | ---- | Tree killed |
| Lyerle | 9 | 2 | 12 | 6½ | Tree killed |
| | | | | | |
| Madame Appert | 11 | 5 | 27 | 1½ | |
| Madame Baltet | 8 | 2 | 10 | 4 | Tree killed |
| Madame Caroline Airolles | 12 | 2 | 24 | 1 | |

TABLE VII (Continued). RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

| Variety | Age of trees | Number of years blighted | Number of infections | Diameter of largest wood killed | |
|---|---|---|---|---|---|
| | | | | *in.* | |
| Madame Cherve | 10 | 3 | 7 | 1 | |
| Madame Chervet | 8 | 1 | 6 | 5 | Tree killed |
| Madame du Pois | 11 | 3 | 5 | 1½ | |
| Madame Ernest Baltet | 10 | 3 | 17 | 5 | Tree killed |
| Madame Favre | 11 | 3 | 5 | 1½ | |
| Madame Lyle Baltet | 10 | 4 | 17 | 4½ | Tree killed |
| Mlle, Marguerite Gaujard | 9 | 3 | 9 | 5¼ | Tree killed |
| Madeline | 10 | 2 | 28 | 6 | |
| Magnolia | 9 | 2 | 4 | 2 | |
| Mai | 11 | 3 | 11 | 2½ | |
| Malines | 11 | 4 | 34 | 1 | |
| Manderine | 11 | 3 | 4 | 4 | Tree killed |
| Marguerite | 12 | 2 | 11 | ¾ | |
| Maria Lesuer | 11 | 3 | 12 | 1½ | |
| Marie Benoist | 11 | 4 | 32 | 3 | |
| Marie de Barbee | 12 | 4 | 22 | 2½ | |
| Marie de Nouhes | 11 | 3 | 22 | 5 | Tree killed |
| Mas (Alex) | 9 | 1 | 5 | 3 | |
| Mas (du) | 12 | 4 | 46 | 3½ | |
| Mello | 12 | 4 | 46 | 3½ | |
| Menin | 11 | 3 | 6 | 3 | |
| Mere Perrier | 7 | 1 | 1 | ---- | |
| Messire | 12 | 3 | 4 | 1 | |
| Miller | 10 | 4 | 17 | 2½ | |
| Millet | 11 | 3 | 19 | 1½ | |
| Minster Viger | 11 | 3 | 17 | 2½ | |
| Monchallard | 11 | 4 | 9 | 3½ | |
| Montlucon | 8 | 1 | 2 | ---- | Tree killed |
| Monchy | 12 | 4 | 9 | 3¼ | |
| Moulins Lille | 11 | 4 | 6 | ¾ | |
| Nantes | 10 | 3 | 14 | 1¼ | |
| Napoleon I | 11 | 4 | 5 | 1½ | |
| Napoleon (Prince) | 7 | 1 | 3 | 3 | Tree killed |
| Nemours | 10 | 1 | 7 | 7½ | Tree killed |
| Noel | 11 | 4 | 4 | ¾ | |
| Notaire Lepin | 12 | 5 | 32 | 4 | |
| Oberdieck | 10 | 3 | 19 | 7 | Tree killed |
| Octave Lachambre | 11 | 3 | 7 | 1½ | |
| Old Home | 7 | 0 | 0 | 0 | |
| Olivier | 7 | 1 | 1 | 4 | Tree killed |
| Osmonville | 10 | 3 | 11 | 5 | Tree killed |
| Passe Colmar | 12 | 5 | 18 | 3½ | |
| Passe Crassane | 8 | 3 | 8 | 6 | Tree killed |
| Pathenay | 12 | 3 | 11 | 3 | |
| P. Barry | 6 | 2 | 12 | 2½ | Tree killed |
| Peche | 12 | 5 | 18 | 1¼ | |
| Perrault | 6 | 1 | 2 | 3 | Tree killed |
| Pierre Curie | 9 | 1 | 3 | 4½ | Tree killed |
| Pierre Pepin | 11 | 3 | 7 | 2¾ | |
| Pitmaston | 11 | 2 | 10 | 2½ | |
| Poete Beranger | 10 | 3 | 8 | ½ | |
| Poiteau | 9 | 2 | 28 | 6 | Tree killed |
| Poitevin | 11 | 4 | 22 | 2¾ | |
| Pomologie | 12 | 0 | 0 | ---- | |
| Pound | 10 | 3 | 51 | 10 | Tree killed |
| Precoce de Angers | 12 | 5 | 24 | 2½ | |
| Precoce Trottier | 11 | 4 | 41 | 6 | |
| President Loubet | 11 | 1 | 2 | 1½ | |
| President Loutreul | 12 | 6 | 31 | 2½ | |
| Professeur Barral | 8 | 1 | 3 | 7 | Tree killed |
| Professeur Bozin | 11 | 1 | 2 | 1½ | |
| Professeur Grosdemange | 11 | 2 | 11 | ¾ | |
| Professor Opoix | 10 | 4 | 17 | 5 | Tree killed |
| Quimper | 11 | 4 | 23 | 2½ | |

TABLE VII (Continued). RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

| Variety | Age of trees | Number of years blighted | Number of infections | Diameter of largest wood killed | |
|---|---|---|---|---|---|
| | | | | *in.* | |
| Rahard | 8 | 2 | 22 | 4 | Tree killed |
| Rance | 12 | 4 | 21 | 1½ | |
| Reeder | 12 | 4 | 24 | 1½ | |
| Reliance | 10 | 4 | 26 | 2 | |
| Rey | 8 | 2 | 3 | 5 | Tree killed |
| Rheims | 12 | 3 | 16 | 2½ | |
| Rheil | 8 | 2 | 12 | 7 | Tree killed |
| Roosevelt | 8 | 2 | 5 | 5 | Tree killed |
| Rosee de Juillet | 12 | 2 | 4 | 1¾ | |
| Rossney | 8 | 1 | 15 | 1 | |
| Rouennaise | 10 | 4 | 12 | 5 | Tree killed |
| Royal d'Hiver | 9 | 3 | 14 | 6 | Tree killed |
| Royal Vendee | 12 | 3 | 13 | 3 | |
| Saint Andre | 12 | 0 | 0 | .... | |
| Saint Pere | 11 | 3 | 10 | 1½ | |
| Saint Vincent de Paul | 8 | 1 | 9 | 4 | Tree killed |
| Saladin | 11 | 4 | 18 | 6½ | Tree killed |
| Sanguinole (France) | 11 | 4 | 10 | 7 | Tree killed |
| Sanguinole (Italie) | 12 | 3 | 7 | 3 | |
| Santa Claus | 11 | 4 | 13 | 3 | Tree killed |
| Saumur | 11 | 3 | 9 | 1½ | |
| Sec | 12 | 6 | 36 | 2¼ | |
| Seckel | 11 | 4 | 26 | 1½ | |
| Senateur Belle | 12 | 1 | 1 | ½ | |
| Seneca | 11 | 4 | 30 | 6 | Tree killed |
| Serrurier | 11 | 3 | 9 | 1¾ | |
| Sheldon | 11 | 4 | 64 | 3 | |
| Six | 9 | 2 | 22 | 7½ | Tree killed |
| Smith | 8 | 2 | 4 | 1 | |
| Smyth | 8 | 3 | 9 | 1½ | |
| Snyder | 12 | 3 | 34 | 2½ | |
| Soldat | 11 | 3 | 14 | 1½ | |
| Souvenir | 9 | 2 | 30 | 5¼ | Tree killed |
| Souvenir de Cronstadt | 10 | 3 | 7 | 2½ | |
| Souvenir de Dives | 11 | 2 | 3 | 3 | |
| Souvenir de Guy Bruzon | 9 | 2 | 39 | 2 | |
| Souvenir de Jules Guindon | 10 | 3 | 8 | 7 | Tree killed |
| Souvenir de Valmy | 9 | 2 | 32 | 5½ | Tree killed |
| Spanish | 11 | 2 | 12 | 4 | |
| Sterkmans | 6 | 1 | 2 | 2¾ | Tree killed |
| Success de la Meilleraye | 11 | 2 | 2 | ¾ | |
| Sudduth | 12 | 4 | 24 | 1 | |
| Summer Colmar | 9 | 2 | 10 | 6½ | Tree killed |
| Summer Doyenne | 12 | 5 | 13 | 1¼ | |
| Superb | 7 | 2 | 2 | ¾ | |
| Superfin | 12 | 3 | 17 | 2 | |
| Surprise | 10 | 1 | 2 | ½ | |
| Suzette | 11 | 4 | 35 | 3 | |
| Taberier de Boulogne | 8 | 1 | 9 | 6 | Tree killed |
| Ta Suan Li | 5 | 1 | 2 | ½ | |
| Tedrow Beauty | 8 | 2 | 7 | 1½ | |
| Theodore Williams | 11 | 2 | 8 | 2 | |
| Thirriott | 10 | 3 | 14 | 4½ | Tree killed |
| Tongres | 11 | 5 | 83 | 4 | |
| Totleben | 12 | 4 | 28 | 3½ | |
| Tougard | 10 | 4 | 27 | 5¾ | Tree killed |
| Trevoux | 11 | 2 | 19 | 1 | |
| Treyve | 10 | 4 | 14 | 1 | |
| Triomphe Jodoigne | 8 | 1 | 4 | 8 | Tree killed |
| Triomphe de Tourney | 12 | 5 | 19 | 1½ | |
| Triomphe Touraine | 12 | 4 | 27 | 2½ | |
| Tyson | 11 | 3 | 18 | 1 | |
| Urbaniste | 8 | 1 | 3 | .... | Tree killed |
| Vaillant | 12 | 5 | 50 | 2½ | |
| Vaisse | 12 | 4 | 47 | 3½ | |

TABLE VII (Concluded). RECORD OF NATURAL INFECTIONS IN THE VARIETY ORCHARD

| Variety | Age of trees | Number of years blighted | Number of infections | Diameter of largest wood killed *in.* | |
|---|---|---|---|---|---|
| Van Mons (Present) | 11 | 3 | 17 | 8 | Tree killed |
| Varenne | 12 | 4 | 9 | 2¼ | |
| Vauquelin | 12 | 3 | 33 | 3½ | |
| Vaux | 10 | 2 | 27 | 5 | Tree killed |
| Vermont Beauty | 11 | 5 | 16 | 4½ | |
| Vicar | 11 | 4 | 32 | 8 | Tree killed |
| Vienne | 10 | 5 | 27 | 5¾ | Tree killed |
| Vigneau | 12 | 5 | 39 | 6 | Tree killed |
| Vilmorin | 12 | 3 | 4 | 1 | |
| Virginie Baltet | 9 | 2 | 14 | 5¼ | Tree killed |
| Vital | 8 | 1 | 1 | 5 | Tree killed |
| Warner | 10 | 3 | 109 | 7 | |
| Weidner | 10 | 3 | 29 | 10 | Tree killed |
| White Doyenne | 12 | 5 | 12 | 1½ | |
| Williams de Hiver | 12 | 4 | 23 | 3½ | |
| Windsor | 8 | 3 | 12 | 2½ | |
| Winter Bartlett | 12 | 6 | 94 | 4 | |
| Winter Nelis | 11 | 4 | 14 | 3 | |
| Worden Seckel | 10 | 4 | 50 | 2½ | |
| Ya Kuang Li | 7 | 2 | 3 | ½ | |

# PART II. CHARACTERISTICS OF PEAR SPECIES AND PEAR STOCKS

## DISCUSSION OF THE MOST IMPORTANT SPECIES

### PYRUS COMMUNIS

*Pyrus communis,* commonly known as the European or cultivated pear, includes the leading varieties cultivated in America and also the French seedlings used as stocks. It is a native of Europe and southwestern Asia and is most abundant in Austria. It has been widely cultivated throughout Europe for centuries and in many parts of the United States for the past two hundred years. About the middle of the last century it received a great deal of attention from American pomologists, special consideration being given to the introduction and testing of new European varieties. The finest of these varieties are superior in quality to those of any other species.

**Description.** This species is so well known and so distinct from other species of pears that a complete description is unnecessary here. Attention need be called only to the most salient characteristics. The tree is a vigorous, upright grower with a central leader and a coneshaped top. It possesses many stout, medium sized thorns. The bark is usually brown or purplish-brown in color, the shoots being pubescent when young but usually becoming glabrous with advanced growth. This species is readily distinguished from all others by its small or medium sized leaves, which are oval or oblong-ovate, with short rounded or acute apex, and rounded base; the margins are either entire or possess small crenate-serrate teeth. The white, medium sized flowers have rounded petals, possess eighteen to twenty stamens and always five pistils, and are borne in small compact clusters. The fruit of the wild type is approximately an inch in diameter, usually pyriform, green or greenish-yellow in color, with a persistent calyx, white, soft, juicy flesh, and a five celled core.

**Climatic requirements.** *P. communis* is admirably adapted to the milder portions of the temperature zone. In America it reaches its greatest perfection in the northern states east of and adjacent to the Great Lakes, and on the Pacific Coast. It is not hardy in the extreme north or in the upper Mississippi Valley. While the trees will grow in the southern states, they are unproductive and are speedily destroyed by the ravages of fire blight. Bartlett is the most cosmopolitan of all the *P. communis* varieties and is successfully grown over a greater range of territory than any of the others.

**Soil adaptation.** This species will grow on a great variety of soils, ranging from sandy loams to heavy clays and adobes. It reaches its greatest perfection, however, on the heavier types—the fertile silty and heavy clay loams and certain types of clays and adobes. Bartlett and Howell can be successfully grown on a far greater variety of soils than Anjou, Bosc and Comice and some of the other varieties. In Southern Oregon Bartlett, Bosc, Howell, and Winter Nelis are very successfully grown on heavy adobe soils which are unsuited to most of the other types of fruit. On fertile adobe soils these varieties are productive and develop flavor and keeping qualities seldom attained on any other type of land.

While this species thrives best on well drained soils, it will tolerate wet soils better than any of the other common fruit trees; much better, also, than the Japan pear stock or any other species of pears with the possible exception of *P. calleryana* and *P. betulaefolia.* This is particularly true in the mild winter climate of the Pacific Coast, where such varieties as Bartlett and Winter Nelis on French pear stock are sometimes grown on soils which are so wet during part of the winter that practically all other fruit trees would speedily perish. Naturally such soils do not produce as good results as those which are well drained, but when planted to the varieties mentioned above the returns are far more satisfactory than would be expected by one familiar with the culture of other tree fruits. In colder climates trees on soils of this character would undoubtedly survive only a short time.

While the French stock will withstand the effects of a limited amount of alkali, it is readily killed by a quantity which *P. betulaefolia* will endure with impunity.

**Value as a rootstock.** Until comparatively recent years the French stock was the only species of Pyrus used as a rootstock for American pears, and at this time it is more extensively used than any other. It makes a strong, smooth union with all the European varieties and the trees are vigorous and long lived. This stock is remarkably well adapted to the climatic and soil conditions in the leading pear districts of the Pacific Coast. In the portions of this territory where root blight is not troublesome this stock should be given preference over all others at the present time. In those regions, however, where root blight is very troublesome a large proportion of the French seedlings now available will not prove satisfactory. In such regions it will undoubtedly prove safer to use a more blight-resistant stock, such as *P. calleryana.*

In the northern states and particularly in regions where root blight is not an important factor this species is undoubtedly the safest one to use at the present time. It will endure lower temperatures than the Japanese pear, hence is preferable to that stock in the colder portions of America. In the warmer portions of the South the French stock is far more susceptible to blight and certain root rots than the Japanese stock, and there it has been largely replaced by the latter.

As shown in Table V, a few of our *P. communis* varieties, notably Old Home, Farmingdale and Longworth, have manifested a high degree of resistance to blight. The fruit of these is of little importance, but the trees are of great value as blight-resistant trunk and body stocks for our better commercial varieties. Old Home is particularly promising for this purpose because of its hardiness, extreme vigor, resistance to blight, and perfectly formed framework. These varieties of *P. communis* when used as trunk and framework stocks suffer less from winter injury in the wet winter climate of Southern Oregon than those of certain other species, notably *P. ussuriensis.*

**Pear Blight.** The most serious objection to *P. communis* is its extreme susceptibility to pear blight. It is far more susceptible to this disease than any other important species. In America the loss sustained by *P. communis* varieties from blight has undoubtedly been greater than that of any species of fruit from any other disease. Furthermore, this disease has unquestionably been responsible for greater losses in American pears than all

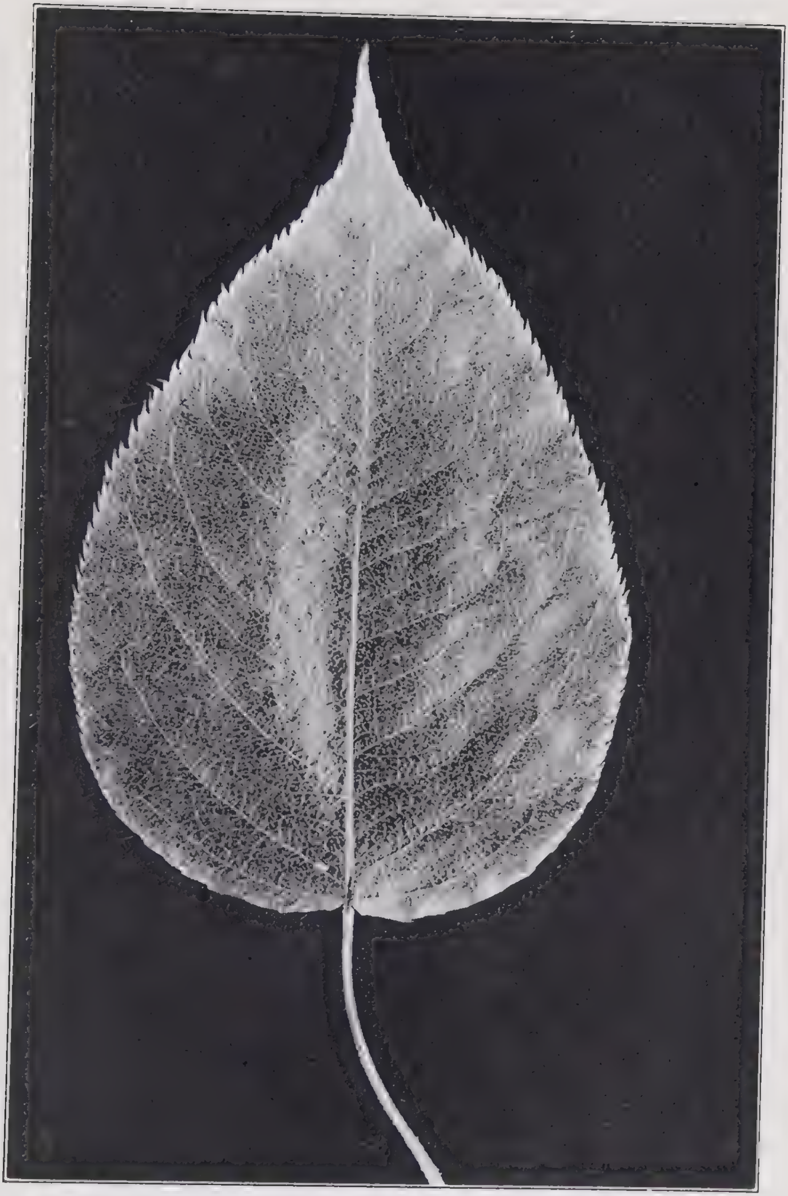

Fig. 23. Leaf of Japanese Sand Pear *(P. serotina)*.

other pear diseases combined, and it has been the greatest hindrance to the development of the pear industry in this country.

The inoculation results obtained with this species have been presented in Tables I, II, V, VI, and VII of this bulletin. All of the French seedlings inoculated have proved to be susceptible in the tips; 74.1 percent of the trunk inoculations developed infections which destroyed two-thirds or more of the tree, and 43.8 percent of the root inoculations were successful. The percentage of root infections, therefore, is nearly twice as great as that in any of the other species and almost five times as great as that in *P. calleryana.* A far greater percentage of the cultivated varieties of this species have proved susceptible than in the varieties of the other species.

A small percentage of *P. communis* seedlings, however, were immune in the trunks and roots, and if these can be propagated true to type they will be of great value. Seeds from each of these will be planted separately to determine whether any of the trees will transmit to a high percentage of their seedlings the factor of resistance to blight. If this should prove to be the case such types will thereafter be used as mother trees to supply the desired seeds. These trees can also be propagated true to type from root cuttings, and experiments are now in progress to determine whether this can be successfully done on a commercial scale. If so, one of our most perplexing rootstock problems will have been solved.

**Leaf blight.** The French pear seedlings are very susceptible to leaf blight *(Fabraea maculata).* The effects of this disease are particularly disastrous to these seedlings in the humid summer climate of the eastern states. In those regions this fungus attacks the leaves and when prevalent it stunts the growth of the trees and often defoliates them long before the end of the growing season, thus materially shortening the budding season with this stock, and in some years the growth is so impaired that no budding can be done. In contrast to this, most of the Chinese species are remarkably resistant to leaf blight and have a long budding season.

**Mushroom Root Rot.** The French pear seedlings are remarkably resistant to Mushroom Root Rot *(Armillaria mellea)*, a disease which is found in many of the fruit districts of the Pacific Coast. This is a malady which often attacks and in numerous cases destroys the roots of a great many varieties of our common fruit trees. By reason of possessing such a marked degree of resistance to this disease, the French pear virtually stands in a class by itself. While trees of this species affected by Mushroom Root Rot have been found, they are extremely rare and the injury seldom proves serious. This is indeed fortunate, since the disease is difficult to combat when susceptible trees become infected. The high degree of resistance shown by the French seedlings stands out in sharp contrast to the marked susceptibility of the Japanese pear seedlings to this disease.

**Pear Woolly Aphis.** Unfortunately, the French seedlings are highly susceptible to the Pear Woolly Aphis *(Eriosoma pyricola).* This insect is abundant in most of the pear districts of the Pacific Coast. It prefers the roots of the *P. communis* seedlings and does the greatest damage in nurseries and young orchards. It saps the vitality of the young trees, thus seriously stunting them, and in rare cases, during very dry seasons, the trees are killed. Woolly aphis exacts a heavy toll from the nurseryman as it often damages a high percentage of trees on this stock to an extent which precludes their sale.

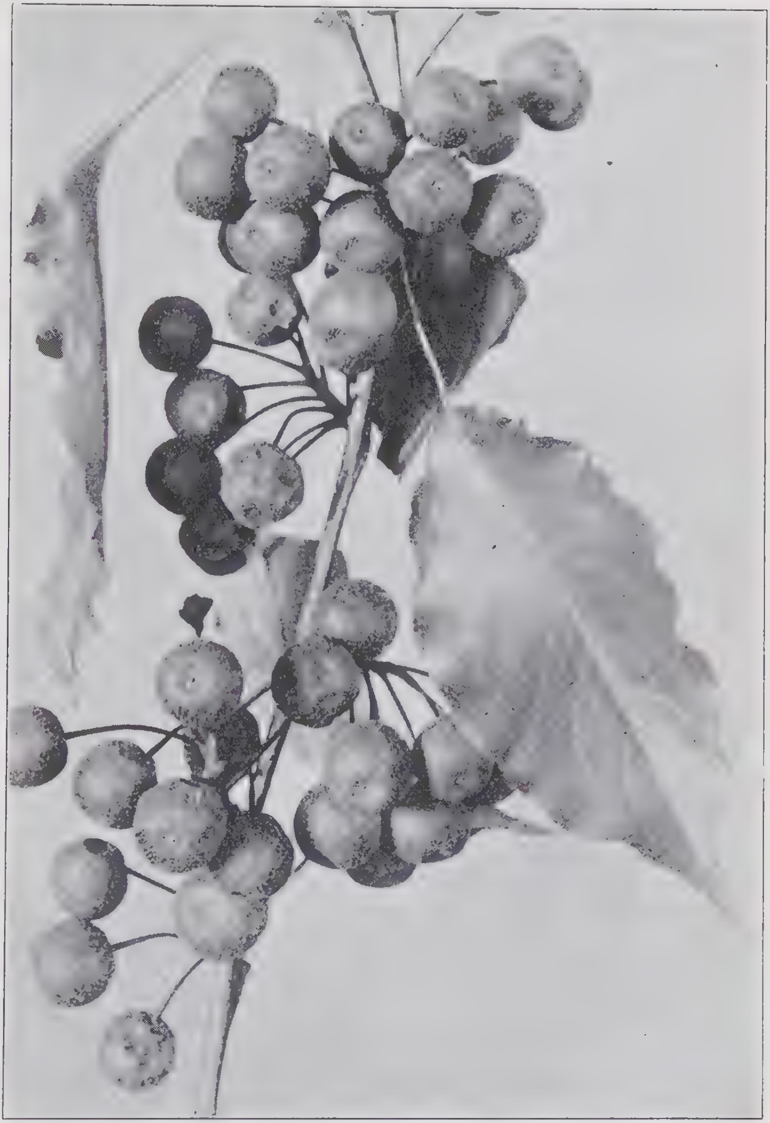

Fig. 24. Fruit and leaves of *P. koehnei*. This species appears very promising as a stock for very warm climates.

This insect has been responsible, in a large measure, for the displacement of the French stock in nurseries on the Pacific Coast by the more resistant Japanese stock.

To summarize: the French stock has a number of valuable characteristics; it makes a fine stock for American pears and the union with them is excellent; it will endure wet, shallow, and very heavy soils better than any other pear stock except possibly *P. calleryana;* and it is highly resistant to Mushroom Root Rot. Its objectionable characteristics are susceptibility to pear blight, leaf blight, and Pear Woolly Aphis.

**Pear breeding.** In the production of varieties of superior quality *Pyrus communis* is the most important of all species of pears. According to American and European standards the finest *P. communis* varieties are superior to those of any other species. They possess a combination of admirable qualities, including size, form, juiciness, tenderness of flesh, and delicacy of flavor, found in no other species. These characteristics must enter into any new varieties produced for American and European consumption; hence in breeding work this species must be used as one of the parents. In the production of new varieties we must also strive for certain characteristics not now found in our best pears, and the most vital of these is resistance to blight. Among cultivated pears this characteristic is most pronounced in certain varieties of *P. ussuriensis.* Judging from all available evidence it seems probable that we are most likely to develop the desired new pears from hybrids of the best varieties of *P. communis* and *P. ussuriensis.* The best *P. communis* varieties for this purpose, which have already been tested, are Bartlett, Anjou, Bosc, Comice, and Winter Nelis.

## PYRUS CALLERYANA

*Pyrus calleryana* is a native of central China, being especially abundant in the Yangtze Kiang River Valley. It is widely distributed from near sea level in eastern China to more than a thousand miles inland and to an elevation of at least five thousand feet. The most northern limits of the species in China are not known. In 1919 the writer found large trees growing vigorously in southern Shantung Province, considerably further north than any point from which it had formerly been reported, and this is probably near its northern limit. Its southern limit has not been determined. It has been collected, however, in several other provinces at least two hundred miles south of the Yangtze river.

A sub-species of *P. calleryana,* known as *Pyrus calleryana-dimorphophylla,* has been found by Japanese botanists and also by the writer in various places in the Ise Province of southern Japan. This sub-species produces two types; one, which is rare, with leaves similar to the Chinese form, and another with long, narrow leaves. The fruit is identical with that of *P. calleryana.* The trees have not proved as vigorous or as resistant to blight as the typical species found in China.

The species is characterized as follows: trees medium to large in size and vigorous; the bark on younger wood smooth and glossy, but on trunk and older wood more or less furrowed, seldom, however, with transverse checks such as are found in *Pyrus betulaefolia.* It is readily distinguished from all other species by its leaves, which are medium to large in size, ovate, with a green, glossy surface and rounded or crenate marginal teeth. On young seedlings the leaves are usually ovate-lanceolate, slightly folded upward and with margins crimped. The trees bloom very early, usually beginning one day later than the wild type of *Pyrus ussuriensis*. The flowers are borne in great abundance, laterally, on the previous year's wood and on spurs of older wood. With the exception of *Pyrus betulaefolia* it probably produces more blossoms than any other species of Pyrus. The blossoms are small, from two-thirds to three-fourths of an inch across, petals white and round, borne on small short claws. The number of stamens varies from eighteen to twenty, with beautiful dark red anthers. It has two and rarely three pistils. The fruit is borne in clusters, is small—about one-third of an inch in diameter—round and entirely covered with russet, and the calyx is deciduous; it possesses a thin layer of greenish flesh, and an extremely heavy, thick continuous

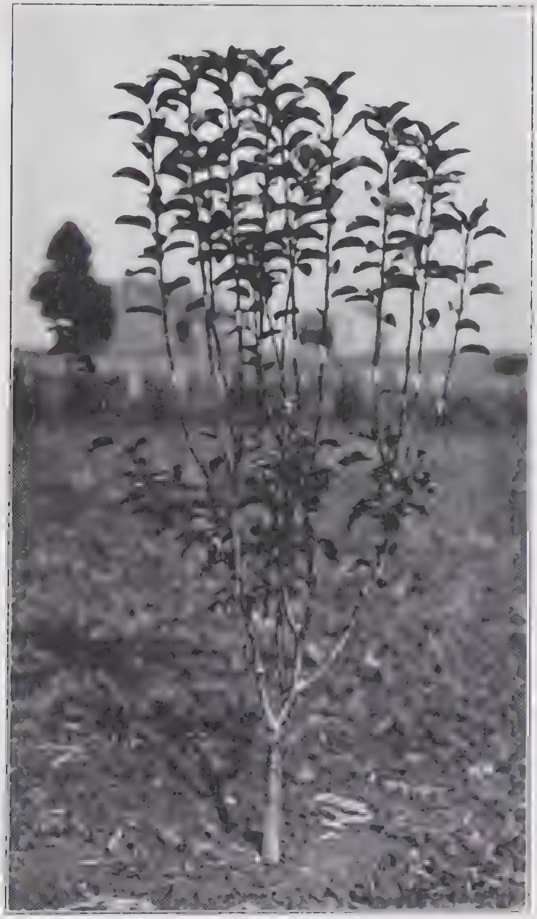

Fig. 25. Showing blight resistant stock properly top-worked with commercial variety. The buds of the commercial variety were inserted at points indicated by the white bands on the young branches.

layer of large grit or stone cells around the core; usually two and occasionally three celled, with two very small, dark brown or black seeds in each cell.

**Introduction into the United States.** *Pyrus calleryana,* so far as can be determined, has had a very brief history in the United States. The earliest introductions were those made in 1908 by Mr. E. H. Wilson, of the Arnold Arboretum. Mr. Wilson collected the seed in the western part of the Hupeh Province, in China, at an elevation of four to five thousand feet. This type has proved hardy near Boston, Massachusetts.

In 1917 the writer and the late F. N. Meyer of the U. S. Department of Agriculture collected a large quantity of seed in several places in central Hupeh Province near Kingmen, and in the mountains west of Ichang, China. From these seeds thousands of plants were grown, many of which have been used as rootstocks, and others have been thoroughly tested for blight resistance. In 1919 the writer collected additional seed and studied the species in southern Shantung Province, China.

**Blight resistance.** The results of the work on blight resistance in this species are presented in Table II of this Bulletin. These results show that a higher percentage of the roots and trunks of *P. calleryana* are resistant to blight than in any other important species. Only 2.5 percent of the trees inoculated in the trunks blighted into the roots and only 9.1 percent of the root inoculations were successful. This is fortunate, indeed, since this species also possesses other characteristics which make it very valuable as a stock.

**Economic importance.** The fruit of *P. calleryana* is of no value, as it is extremely small, contains little flesh, is very gritty and possesses a wretched flavor.

**As a stock.** *P. calleryana* promises to be a valuable stock for American pears.[6] A large number of seedlings were grafted with our leading commercial varieties in the spring of 1919. These have been planted in a stock test orchard and are being carefully studied. The trees on this stock have made a splendid growth, surpassing in vigor and uniformity the same varieties on the standard French seedlings and those on *P. ussuriensis,* as well as on all the other stocks planted at the same time and in adjacent rows.

This stock has made a perfect union with Bartlett and Anjou, stock and scion being identical in size, and without the slightest enlargement at the union. The Bosc, Howell and Winter Nelis have made a splendid growth on this stock and the union is strong and apparently congenial. Part of the trees of each of these three varieties, however, are slightly larger in diameter than the stock below the union. If the difference in size does not become greater than it is at present it will not prove detrimental. These trees were grafted from twelve to twenty-four inches above the ground where the unions can be easily studied. It is quite probable, judging from other evidence which we have, that no differences in size of stock and scion would exist if these trees had been grafted at or below the surface of the ground. The Comice trees have also made a fine growth on this stock, but this variety is considerably larger than the stock. Comice shows this characteristic on any stock when grafted above the ground, but not when worked at or below the ground. Some of these Comice trees top-worked on other French varieties above ground, and which have far outgrown the stock, are among the most productive old trees of this variety in Oregon. Until we have further evi-

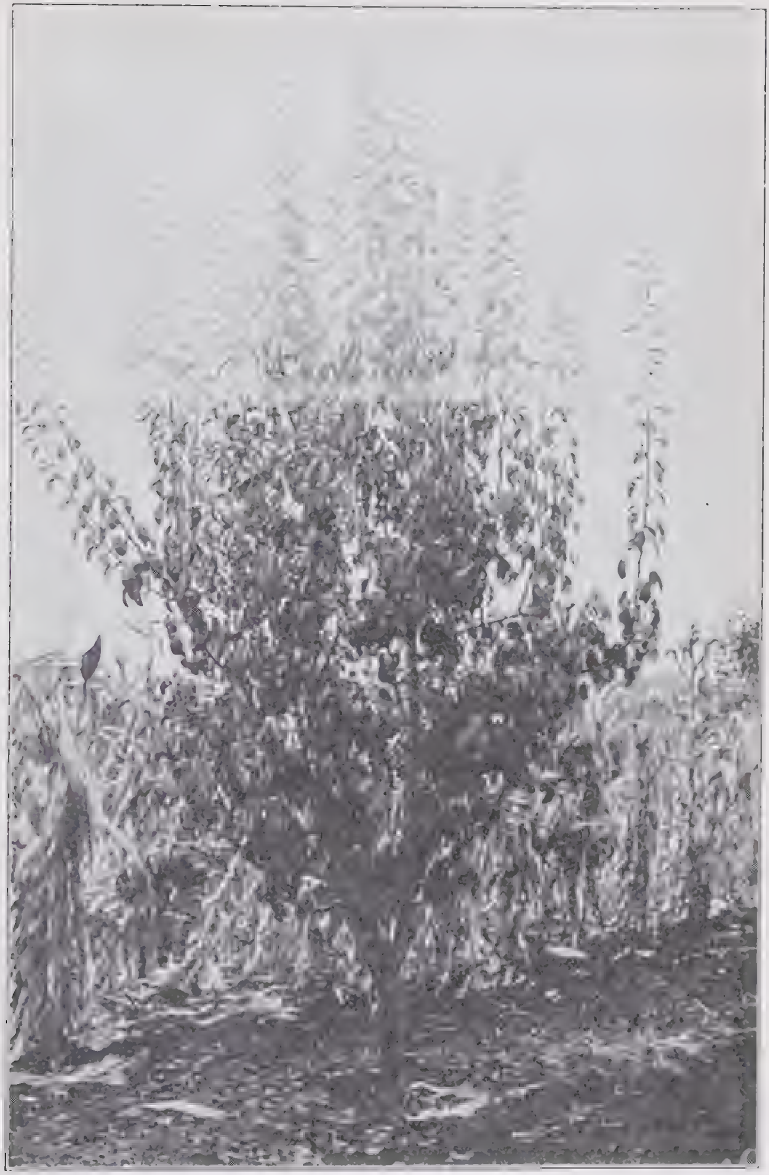

Fig. 26. Typical tree of Old Home showing vigor, well shaped framework, and freedom from blight.

dence, we recommend grafting the Comice at the surface of the ground when it is propagated on *P. calleryana.*

For Southern Oregon our advice is to use *P. calleryana,* or other seedlings, only for the root system of our pear trees and that certain resistant body stocks be budded or grafted on to this at or below the surface of the ground. For such trunk stocks there are several varieties and types which appear promising at this time. Among these are Old Home, Variolosa, Farmingdale, and probably others. In one of our stock orchards Old Home has been budded on *P. calleryana* and other stocks in this manner. The trees have made an excellent growth and the union appears to be perfect. These trees are very uniform and are larger and more vigorous than Old Home on French or any other rootstocks. These Old Home trees are now three years old and will be top-worked with commercial varieties.

It is quite possible that some of the selected and tested blight resistant strains of *P. calleryana* which produce a very vigorous, upright growth of desirable form, may be used for the trunk and frame work. These should be propagated only by budding or grafting to keep them true to type.

One of the advantages of *P. calleryana* is that the seedlings cannot be confused with those of any other species. The leaves are so characteristic and so distinct from those of all other pear stocks that any nurseryman can readily identify this species. Furthermore, there should be little difficulty in getting reliable seed, for it is only about one-fourth as large as that of French, Japanese, and *P. ussuriensis* seed, and can be distinguished at a glance from these species. Unfortunately the seed of *P. calleryana* is very similar to that of *P. betulaefolia;* in fact, it is very difficult to distinguish between them. Furthermore, there is danger of getting a mixture of the two, since both species are common in central China, and the exterior of the fruit as well as the seed of both, is similar in appearance. The appearance of the trees of these two species, however, is so distinct that any collector can readily distinguish them. While the exterior of the fruit of these two species is similar, the interior is very distinct. *P. calleryana* contains an abundance of large and very conspicuous grit cells, while *P. betulaefolia* usually contains none. In the nursery the *P. calleryana* seedlings, with their glossy bark and green, glossy, ovate leaves with crenate margins, can be distinguished at a glance from the light gray, fuzzy shoots and light fuzzy, lanceolate, coarsely serrated leaves of *P. betulaefolia.* Fortunately, the College of Agriculture, at Nanking University, Nanking, China, is making a specialty of collecting and supplying American nurserymen with reliable seed of *P. calleryana. P. calleryana* seed germinates quickly and should not be stratified for more than one month before planting.

**Types of root system.** The root systems of the various seedlings of this species show marked variation in habit of growth. Part of the seedlings develop a highly desirable, well branched root system even without transplanting. Other trees have a tendency to produce a very long tap-root with few side or branch roots. On deep, mellow soils some of these trees have produced a tap-root four to five feet long with few or no side roots. This has occurred only in trees which had not been transplanted. This habit must be and can be overcome. We have found that all of the trees develop well branched root systems if the seedlings are dug when one year old, the tap-root cut back to eight or ten inches, and the tree transplanted. Fortunately, this is the practice usually followed by nurserymen with pear stocks. With *P. calleryana* such transplanting is absolutely necessary for best results. In ordering trees on this stock the grower should insist on getting well branched root systems.

**Resistance to Woolly Aphis.** One of the most important characteristics of *P. calleryana* is its high degree of resistance to the Pear Woolly Aphis. This insect is a serious pest on French pear stocks on the Pacific Coast. Among the many seedlings of the French pear stock of various ages at this Station it is difficult, during late summer and early fall, to find any which are free from this aphis. Very often the French roots are literally

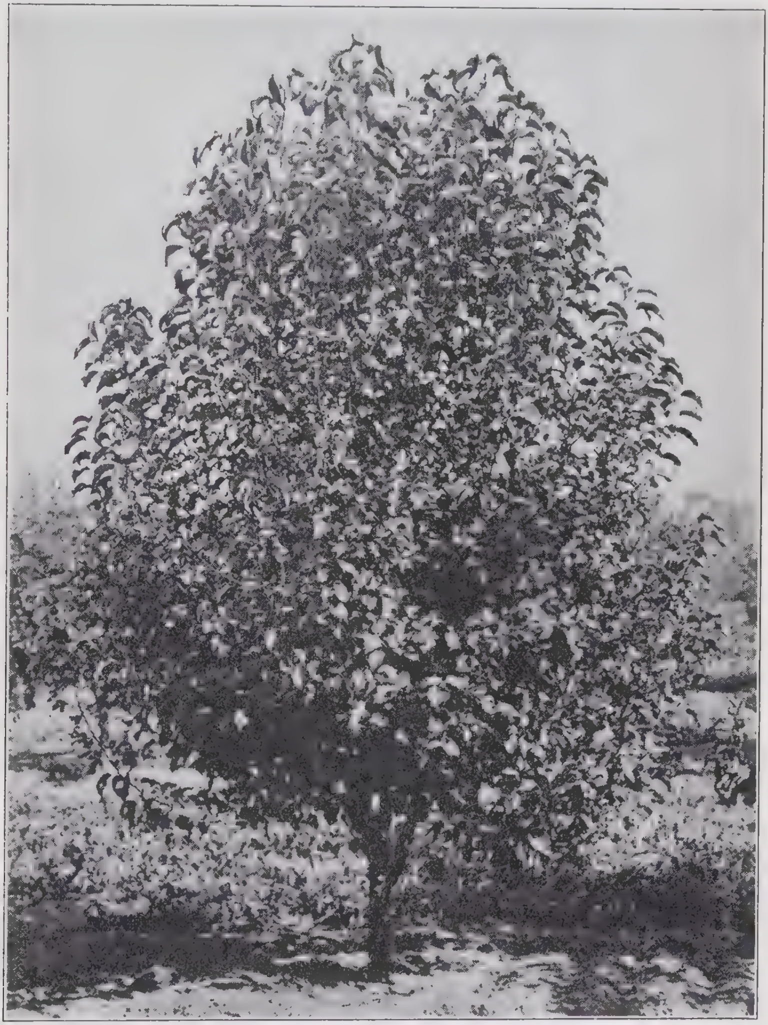

Fig. 27. Four-year-old seedling of cultivated *P. ussuriensis.*

covered with white masses of it. Under identical conditions and often in adjoining rows, the roots of *P. calleryana* seedlings are entirely free from this insect. In thousands of seedlings which have been dug at this Station these aphids are rarely found on *P. calleryana* and in no case has there been a sufficient number on the roots to produce the slightest injury. In this respect *P. calleryana* appears to be superior to all other species in our collection.

**Soil adaptations.** Judging from the observations made in the Orient, *P. calleryana* is adapted to a great variety of soil conditions. The writer has seen it growing there in soils varying from granite and coarse sands to very heavy clay, and it is apparently at home on all types. It appears to be able to withstand equally great variation in soil moisture conditions. It was often observed growing on very dry mountainsides, on various valley lands, along streams, and in wet, poorly drained swamps. The writer observed and photographed one tree actually growing in a pond and the species is very common along the margins of swamps. Naturally, the largest and most vigorous trees were on rich, deep, moist, well drained valley soils. While it grows on cliffs and mountainsides covered with a very thin layer of soil, this is in a region where the summer rainfall is heavy and even then the trees are much smaller than those on deeper and more fertile soils.

When used as a rootstock it is probable that this species will grow successfully on as great variety of soils as the very cosmopolitan French stock.

Trees propagated on this stock have been planted on various soils at the Experiment Station and other places in this Valley, ranging from clay loams to heavy adobes. Up to the present time these young trees have made a very satisfactory growth. One young orchard of this species on a dry hillside has made a far more satisfactory growth than cultivated *P. ussuriensis* growing under the same conditions.

**Climatic adaptations.** Since this species comes from central China where the summers are hot and humid and the winters very mild, it is probable that it will not endure the low temperature in most of our northern states. One of the surprising things about the species, however, is that some forms are hardy at Boston, Massachusetts. These forms were grown from seed collected at high altitudes in China. All of the forms of this species have proved perfectly hardy at this Experiment Station, where the temperature has gone below zero only one time. In the unprecedented freeze of December, 1919, when the temperature went to ten degrees below zero, none of the types from central China were injured. Following this freeze the cambium of the branches and trunk was dark brown or black, and remained so until the following spring, indicating serious injury. However, in the early spring they began growing at the normal time and made a very vigorous growth without showing the slightest effect of the freeze. The roots showed no discoloration at any time. Nevertheless, this stock is not recommended for cold climates. Until we have further evidence, it should not be used where the temperature goes lower than ten degrees below zero, and then only for rootstocks. It appears to be particularly well adapted to the mild climate of Southern Oregon and California.

Judging from conditions under which it thrives in its native habitat, this species should be well adapted to the southern states and especially the Gulf Coast states, because the summer climatic conditions there are similar to those of central China. The few plantings made there have been very suc-

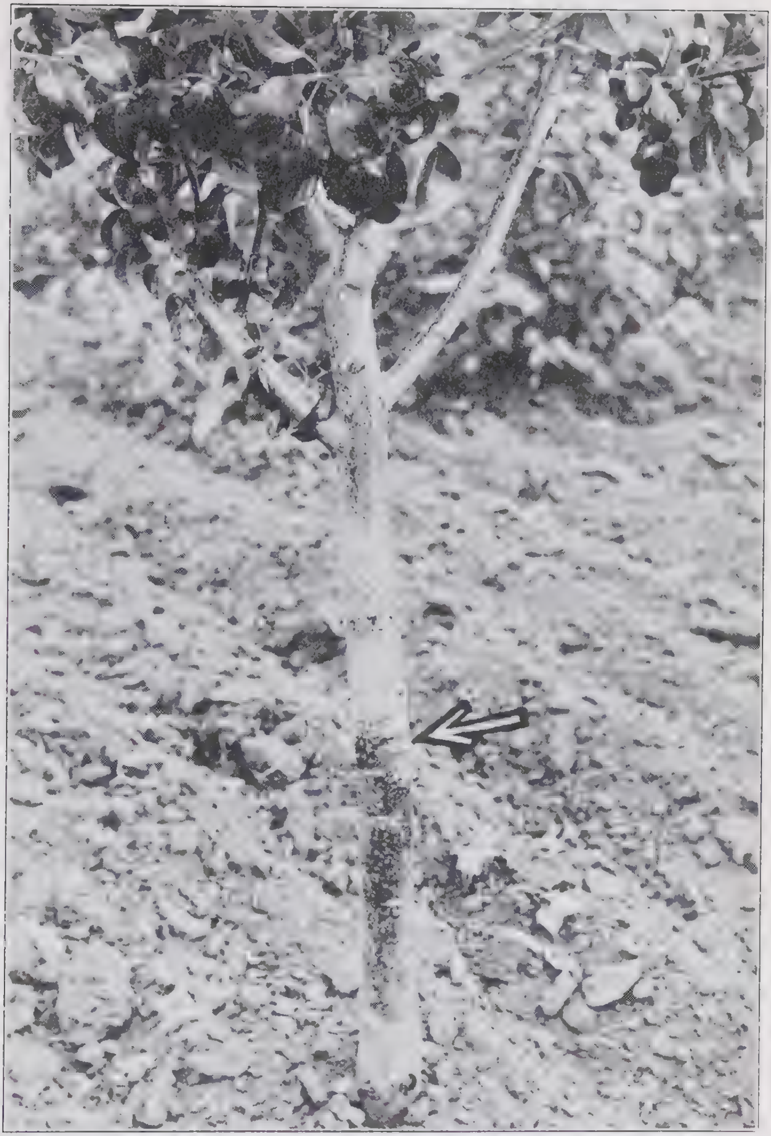

Fig. 28. Showing Anjou graft on cultivated *P. ussuriensis*. Note the perfect union at point on trunk indicated by arrow.

cessful. Trees sent to Florida and Mississippi have made a clean and vigorous growth and appear to be perfectly at home.

This species is able to endure drought much better than *P. ussuriensis*. Growing side by side with the latter on dry sandy soil underlaid with gravel beds, the leaves have never shown the slightest sign of sunburn or wilting, while leaves of *P. ussuriensis* have been badly sunburned and in extreme cases have dropped off. Naturally, under such dry conditions the trees are not as vigorous as on deep, moist soils.

It is probable that trees grown from seeds collected in the warm regions within the southern limits of the species and at low altitudes will not prove as hardy as trees from seed collected in the extreme northern limits and the high mountains of central China. Therefore, considerable care should be exercised in purchasing or collecting seeds in China for planting in the United States.

Since this species comes from a region with a comparatively light rainfall during the winter months it will probably prove hardier in the drier parts of this country than in those with a heavy winter rainfall. It will also undoubtedly make a more satisfactory growth in regions with a heavy summer rainfall than it will without irrigation in the drier and hotter portions of the country. Seedlings of this species have proved satisfactory near Washington, D. C.[1] There it is a clean, lusty grower, holding its leaves until late in the fall, and has proved resistant to leaf blight.

In Southern Oregon young seedlings of this species are remarkable for holding their foliage until early winter and often until mid-winter. This is especially true of the young seedlings from one to three years of age. As they grow older they become better adapted to conditions and drop their leaves at a more seasonable time. With the trees in full leaf in November and December, however, they appear to suffer very little from the heavy frosts. This characteristic of retaining their leaves until late in the season is probably due to the long growing season under which this species developed in central China.

*P. calleryana* cannot be considered one of the more promising species for the pear breeder; certainly not for the breeder primarily interested in developing varieties with large fruit of fine flavor. The fruits of this species are extremely small, filled with grit cells and utterly worthless for eating. *P. calleryana* may prove of value in breeding and developing better trunk stocks. It is possible that some of the hybrids between this species and our most resistant American varieties will give us stocks for the trunk and framework which will be even better than the pure *P. calleryana*.

## PYRUS USSURIENSIS

*Pyrus ussuriensis* is a native of extreme northern China, Manchuria, northern Korea and southeastern Siberia. There it is abundant, especially on the rich, valley soils. The trees are moderately vigorous, long lived, and very old specimens attain great size. The writer observed some of these trees in extreme northeastern China which were from two to three feet in diameter and from fifty to seventy-five feet high. Wherever tested in America the wild type of this species has proved a very slow grower. The wood is very heavy and hard, and when young the bark is smooth and of a distinctive greenish-yellow color. The bark on the older trunks becomes dark in color and deeply and characteristically furrowed and checked.

The leaves are glossy, medium to large, broadly ovate in the wild type, varying from ovate to oblong-ovate in the cultivated varieties, abruptly pointed and often twisted; and on most of the young seedlings of the cultivated types the leaves are folded upwards and with the edges usually waved or crimped. The wild type and some of the cultivated varieties—particularly Man Yuan Hsiang—often produce a rosette of leaves at the end of the branches. The margins of the leaves are always setose-serrate, with the bristles longer than those of any other species of Pyrus.

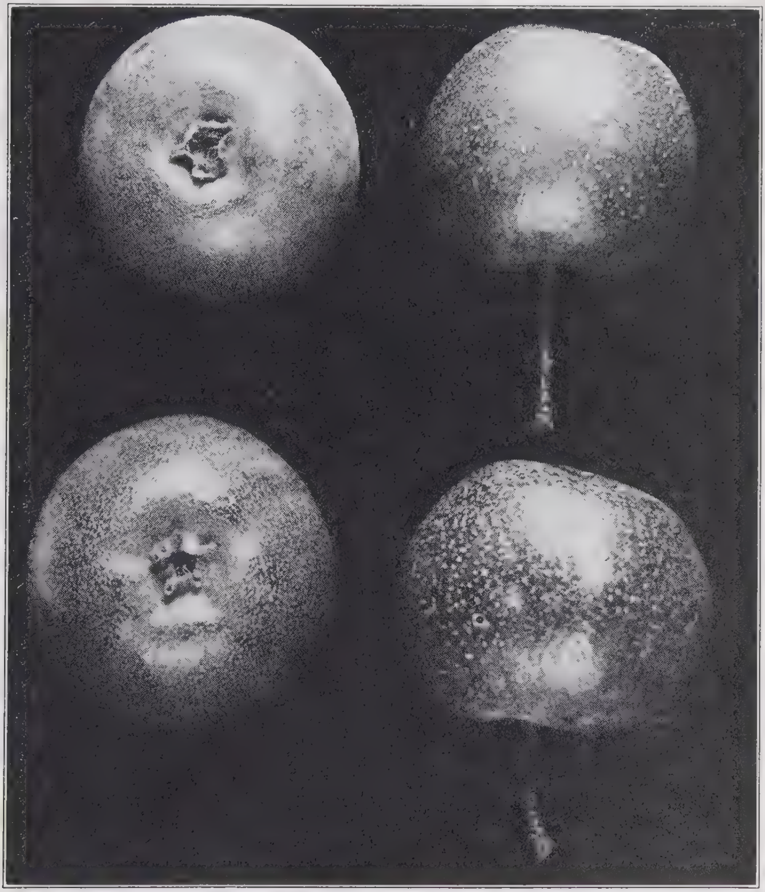

Fig. 29. Fruit of Ba Li Hsiang, an immune variety of *P. ussuriensis*. This has given a higher percentage of immune seedlings than any other variety. Fruit natural size.

The wild forms and some cultivated varieties bloom earlier than any other species, preceding those of our American varieties by ten days to two weeks. The blossom buds are a beautiful reddish pink in color. The flowers are larger than those of any other pear and vary in color from pink to white in different varieties. The petals are very large, obovate, slightly clawed; stamens vary from eighteen to twenty and bear beautiful, large, red anthers. There are always five pistils and this characteristic distinguishes the species from all the other distinct species of northern China.

The fruit of the wild type is from three-fourths to one inch in diameter, round or slightly flattened, greenish-yellow in color, with often a red cheek, a persistent, spreading or erect calyx, and a very short, thick stem. In the wild forms the flesh is hard, but becomes soft when fully ripe, with a very thick, continuous layer of stone cells around the core. Core, five celled with two large, dark brown or black seeds in each cell. The fruit of the cultivated varieties varies from slightly oblate to obovate in form, and some varieties are soft fleshed, juicy and practically free from grit cells. The flavor varies from acid in the wild forms to mild subacid in many of the cultivated varieties. This flavor is agreeable, sprightly and quite distinct from the insipid sand pears of central China and Japan.

The tree of the wild type is very hardy and is the only species of Pyrus known in Siberia and northern Manchuria. It has been known to endure a temperature of forty degrees below zero and withstands the severe climate of St. Petersburg, Russia. In the United States certain seedlings of this species have proved hardy at Brookings, South Dakota, and in northern Iowa.

**History in the United States.** There is no record of the first introduction of this species into the United States. The oldest tree in this country of which the writer has any knowledge is now growing on the Patten Experimental Farm at Charles City, Iowa. This tree was obtained by Mr. Charles Patten[4] from O. H. Bardhall at Grundy Center, Iowa, in the spring of 1884. Mr. Bardhall obtained his tree in 1880 from the nursery belonging to John Collins & Son at Morristown, New Jersey. There is no record of the source from which John Collins & Son obtained this type. It was advertised as a Chinese pear, with fruit as large as that of the Flemish Beauty, but when the variety came into bearing it produced small, green, hard, sour pears about one inch in diameter. It is probable that Mr. Collins obtained this pear from some sea captain, in the form of seed collected in China. Mr. Collins knew many of the captains of ships that came to Philadelphia and they often presented him with plants and seeds from foreign countries. It is quite probable that the seed originally came from a cultivated variety producing large pears, and that the seedlings reverted to the wild type which bears small, inferior fruit.

Mr. Patten was attracted to this tree because of its great hardiness, as it was not injured by the extremely cold winter of 1883-84 in northern Iowa. He published several articles regarding this type and used it extensively in his breeding work. However, it was always listed and described as a Chinese Sand Pear and designated as *Pyrus sinensis*. In the fall of 1916 the present writer identified it as *Pyrus ussuriensis*. While not immune, it is highly resistant to blight.

In the fall of 1907 Mr. Frank N. Meyer, explorer for the United States Department of Agriculture, collected seeds of this species in extreme northern China,[3] and in eastern Siberia. These seeds were sent to the Department of Agriculture and seedlings were later distributed to several Experiment Stations. The writer obtained propagating wood from one of these seedlings and in our inoculation experiments it has proved highly resistant, although not immune, to blight.

In 1917 the writer found this species in several places in central Manchuria and extreme northeastern China. A considerable quantity of seed and scionwood of some of the wild and cultivated types was obtained, and from this material many trees were grown and tested. Many of the seedlings of the wild type and the cultivated varieties proved highly resistant, and some of them immune.

In 1919 the writer again visited these countries and obtained a large quantity of seeds of the wild and cultivated types, and scionwood from nearly all of the known cultivated varieties of this species. These have been thoroughly tested for blight resistance at this Station, where the wild type proved more resistant than any other species, some cultivated varieties proved immune, and the seedlings of these varieties ranked second only to those of *P. calleryana.* The seedlings of one variety proved even more resistant than *P. calleryana.*

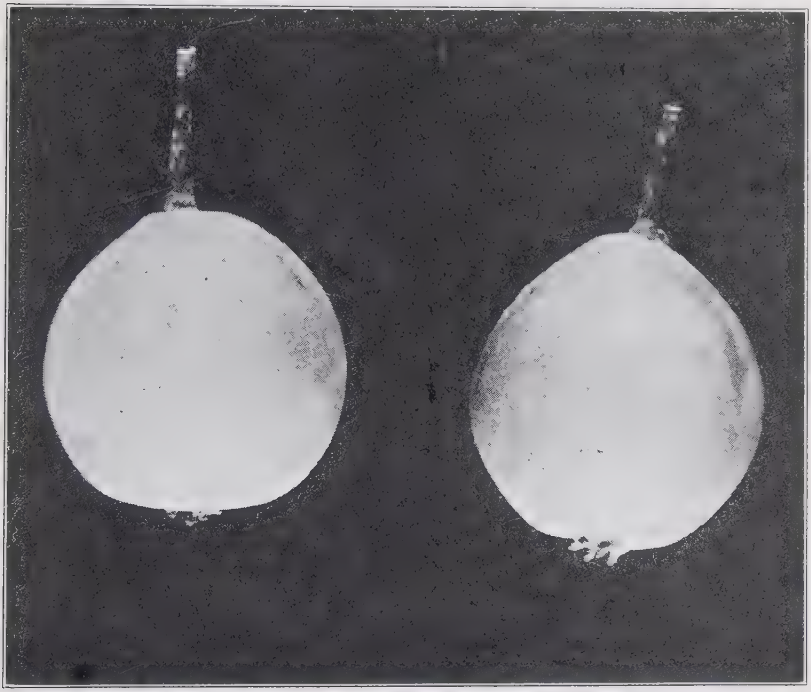

Fig. 30. Fruit of Hsiang Sui Li. (Natural size.) This is one of the two best flavored varieties of *P. ussuriensis* as grown in Southern Oregon. It has proved practically immune to Pear Blight. Flesh soft, juicy, subacid. Desirable for breeding work.

**Climatic adaptations.** *Pyrus ussuriensis* is a native of the cold north, ranging from extreme northeastern China, through Manchuria, into eastern Siberia. In that region the summers are comparatively short, with most of the annual rainfall coming during the months of May, June, and July. The remainder of the year is comparatively dry. The winters are dry and very cold, the low temperatures ranging from ten degrees below zero in northern China, to forty degrees or more below in eastern Siberia.

This species originated in a climate with cold, dry winters and it will endure much lower temperatures in a dry than in a wet winter climate. Young trees of some of these varieties which endure twenty degrees below in the dry winter climate of Manchuria showed heavy trunk injury at two degrees above zero in the damp winter climate of Southern Oregon. Some of the wild types of *P. ussuriensis* have endured a temperature of forty below zero in northern Iowa and in South Dakota. We are finding great variation within this species; some varieties have shown no injury whatever, while in other varieties all the bark on the trunks has been killed.

*P. ussuriensis* will probably prove of greatest value in those portions of the United States having comparatively short, cool, moist summers and dry, cold winters. It is evident that the wild forms are not well adapted to the hot, dry summer climate of Southern Oregon. Here this type suffers from drought unless irrigated, and during the very hottest weather there is considerable sunburn injury to the leaves. Some of the cultivated forms are giving excellent results.

The young seedlings of Guar Li,* a cultivated variety of this species, have made a very satisfactory growth and seem to be well adapted to the climatic and soil conditions prevailing near Washington, D. C.

**Soil adaptation.** In the Orient this species is usually found growing on the deep, rich, silty and sandy loam soils in the valleys and in well protected mountain coves. The best wild groves observed by the writer were those on the silty loam soils in the Hsing Lung Shan Valley at an altitude of twenty-four hundred feet, and about one hundred miles northeast of Peking, China. In that Valley the trees attain enormous size and great age. These soils are well supplied with moisture during the summer months, but are quite dry the remainder of the year. It is probable that the species will not prove satisfactory on poorly drained soils, especially on those that are wet during the winter months, as such conditions are just the opposite of those found in its native home. The trees are sensitive to alkali and become chlorotic on soils containing excessive amounts of lime.

The trees are deep rooted, hence shallow soils underlaid with hardpan will probably prove unsuitable. Sufficient evidence has not yet been obtained to determine this, as the history of the species in this country, with the exception of a few trees, is very brief.

A question of great importance is whether this species will be adapted to the very heavy clay and adobe soils found in certain pear districts of the west. Young trees on this stock have made satisfactory growth on such soil at this Station. These very probably will not prove as long lived or as satisfactory on such heavy soils as on deep, mellow soils.

Since this species has been grown in such a limited way in the United States little is known regarding its resistance or susceptibility to the various fungous diseases attacking the pear in this country. Owing to our dry spring and summer climate, there is far less trouble from fungous diseases at this Station than in the humid eastern part of the United States. Here many of the leaf fungi are unknown. For this reason it is not a satisfactory climate for determining the resistance of the various species to the usual fungous troubles of the pear. Up to the present time these trees have been practically free from leaf spots, various cankers, and scab on the fruit. Seedlings of Guar Li, a variety of this species, proved remarkably free from pear leaf spot near Washington, D. C.

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*See Journal of Heredity for January, 1920, page 29, where this variety is designated as Kuan Li.

One of the most troublesome fungous diseases affecting rootstocks on the Pacific Coast is the Mushroom Root Rot. Growers in California have reported three cases of this disease on young seedlings of *P. ussuriensis*. None have been observed in our collection, although this observation is of little value, since the soil at this Station is free from this fungous trouble. Trees of this and the other promising species of Pyrus have been planted on a plot of soil in the Hood River Valley, Oregon, known to be infected with this disease; hence the evidence will ultimately be obtained on the resistance or susceptibility in these various species.

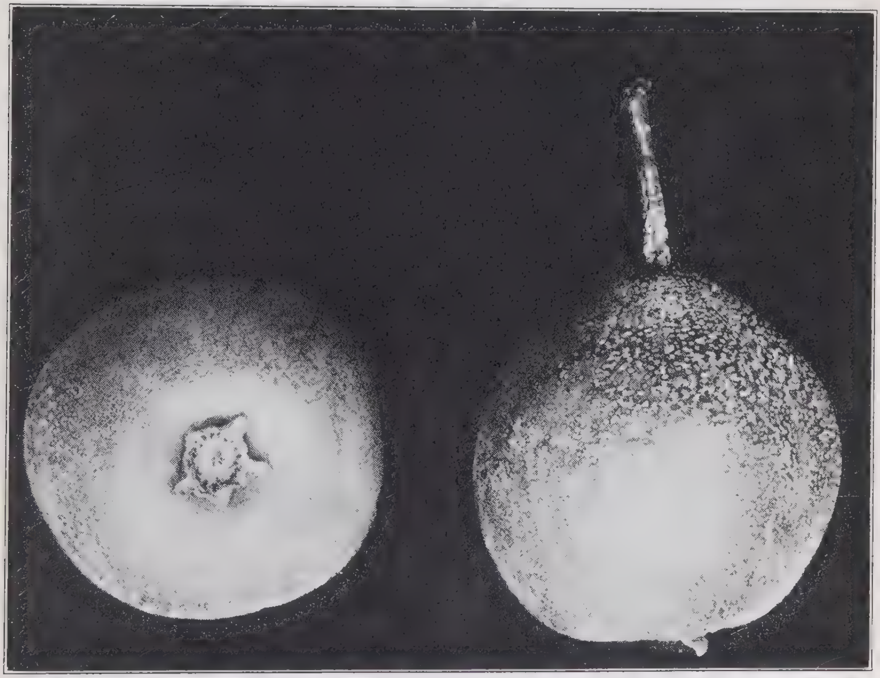

Fig. 31. Fruit of Chien Pa, a cultivated variety of *P. ussuriensis*. This variety has proved immune to Pear Blight. Fruit of good quality in Manchuria. Has not fruited in America.

The Pear Woolly Aphis is a serious menace to the roots of young pear trees in many orchards on the Pacific Coast. It is especially troublesome on the French stock. This insect, up to the present time, has not proved serious on *P. ussuriensis*. While it is found on these seedlings, it is seldom present in sufficient numbers to cause injury. Among hundreds of trees which have been dug at this Station only three have been found which were heavily infested.

**As a rootstock.** Our inoculation work has demonstrated that the wild type of *P. ussuriensis,* and also the Ba Li Hsiang—a cultivated variety of this species—produced a higher percentage of seedlings with roots immune to blight than any of the other species tested. For this reason, this species, and particularly this variety, is being thoroughly tested as a rootstock for our American pears. This work has been in progress for six years, hence the results obtained apply only to young trees.

The results have already demonstrated that the seedlings of the wild type of this species make too slow growth to be satisfactory as stocks for our American varieties. These varieties outgrow the wild stock, and the trunk above the union soon becomes very much larger than the stock. The difference in size eventually becomes so great that the tree breaks off at the union. Therefore, the wild type should not be used as a stock under any conditions, and in future importations of seed every effort should be made to prevent collectors in the Orient from supplying seed of the wild trees. Unfortunately, some of the dealers in the Orient have supplied American nurserymen with this seed. It is practically impossible to distinguish the seed of the wild from that of the cultivated type.

With few exceptions the cultivated varieties of *P. ussuriensis* are far more vigorous than the wild form of this species. This is a natural result since the orchardist in China has selected the most vigorous and productive forms for propagation and cultivation. Most of the seedlings of certain cultivated varieties are very vigorous growers, equaling in this respect the French seedlings which have heretofore been the chief pear stock for American varieties. This is particularly true of the seedlings of Ba Li Hsiang, Guar Li, Hung Guar, and Man Yuan Hsiang. Part of the seedlings of these and of all other varieties, however, are slow growers, apparently reverting to the wild ancestor. These slow growing trees should be discarded by the nurseryman. The best plan is for the orchardist to purchase only the largest sizes of one-year-old trees, not less than four feet and preferably five to six feet high. By doing this he avoids, in a large measure, trees with slow growing root systems. The seedlings of one variety, Ta Suan, have proved especially unsatisfactory, with a very high percentage of dwarf trees. This was unexpected, as the parent variety is one of the most vigorous growers in this species. It is quite possible that the poor growth of these particular seedlings may be due to the seeds having been fertilized with pollen from a very slow growing variety. The cause will be determined by work now in progress.

One variety—the Ba Li Hsiang—has produced seedlings which have proved so superior to those of other varieties that it deserves special consideration. We have already shown in Table III that Ba Li Hsiang is immune to blight. Also that in the seedlings of this variety none of the trunk infections extended into the roots; and further, that only 3.9 percent of the seedlings inoculated in the roots blighted. It has also produced as large a percentage of vigorous seedlings as any *P. ussuriensis* variety in our collection. This is quite remarkable since Ba Li Hsiang is one of the slowest growers of all cultivated varieties of *P. ussuriensis.* Hence the vigor of these seedlings may be due to the male parent which furnished the pollen that fertilized these seeds. Pollination work will be undertaken at once to ascertain what male parents will produce the most vigorous and resistant seedlings with this variety. Since the writer possesses the few other varieties that were present in the orchard in China where he obtained this seed, it will doubtless prove a simple matter to determine the variety that fertilized the seed of Ba Li Hsiang which has given us these valuable seedlings.

Ba Li Hsiang possesses other desirable characteristics as a seed parent. It comes into bearing at a remarkably early age and is one of the most productive varieties in our collection. The small fruit is borne in numerous clusters with from two to six pears in a cluster. Consequently each tree produces a large amount of seed.

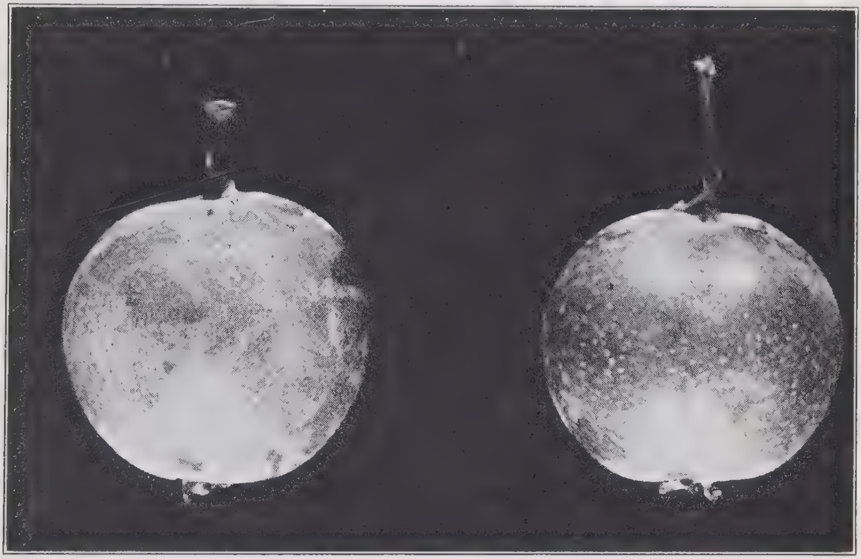

Fig. 32. Fruit of Huang Hsiang Sui, a variety of *P. ussuriensis*. Tree has proved immune to Pear Blight. Fruit of poor quality.

Unfortunately, this variety is very rare in China. The writer found it in only one small, inaccessible mountain valley in extreme northeastern China, within a mile of the Great Wall. Even there it was grown in only a limited way, due probably to its poor quality. Hence the amount of seed of this variety that China could supply at present is insignificant and practically impossible to obtain. It will be necessary for America to produce its own seed of this variety, and seed orchards should be established at once in this country.

The results in Table II show that a few other varieties of *P. ussuriensis* produced a high percentage of seedlings sufficiently resistant to blight. Of these the following are worthy of consideration: Chiu Suan, Guar Li, Hung Guar, Hu Pi Hsiang, Man Yuan Hsiang, and Ta Tze Hsiang. Of these Chiu Suan has proved productive, although not as resistant as Ba Li Hsiang. Man Yuan Hsiang has proved unproductive at this Station. The other varieties have not yet fruited here, hence we know nothing regarding their productiveness in this country. Unless they are productive they will be of little value as seed parents. Ta Tze Hsiang produces a high percentage of dwarf seedlings.

The seedlings of the other varieties, viz: An Li, Chieh Li, Chien Pa, Chiu Tze, Hua Kai and Tzu Ma, proved too susceptible to blight to be of value. However, this result may have been due in a measure to the influence of the unknown pollen parent; particularly so in the case of Chieh Li and Chien Pa, for these two varieties have been very resistant. These varieties, however, cannot be recommended as seed parents until it is shown that they are valuable when pollinated with certain varieties.

It is particularly unfortunate that such a large percentage of the seedlings of Chiu Tze have proved susceptible to blight. This variety is extensively grown in a very accessible region of Manchuria, produces enormous quantities of small fruit, an abundance of seed, and the fruit, owing to its poor quality, sells for a low price. Quantities of this seed would therefore be available at a reasonable price. But since the parent variety and also its seedlings are susceptible to blight, it is probably worthless as a source of seed. The temptation will be great for unscrupulous Chinese seed collectors to substitute this seed for the more expensive seed of desirable varieties.

It is evident from the foregoing discussion that it will be difficult and often impossible to procure quantities of desirable seed of *P. ussuriensis* from the Orient. In fact, the writer, who has had a wide experience in collecting and purchasing seeds in China, realizes that so far as this species is concerned it is difficult and perhaps a hopeless task to procure desirable seed through the Chinese dealers.

Extensive work is being done at the Experiment Station testing out seedlings of the most promising species to determine which are most suitable for stock purposes. Seedlings of Ba Li Hsiang, Guar Li and Man Yuan Hsiang were top-grafted with the leading commercial varieties of Oregon. This was done in 1919, hence the trees are now six years old. All the varieties have made an excellent growth, although there is some variation within each variety, due to differences in vigor in the seedlings. The trees on these seedlings of *P. ussuriensis* varieties average larger than those on French pear seedlings. The unions of Anjou, Bartlett, and Bosc are perfect on this stock. The Howell and Winter Nelis unions are also good, although in each of these varieties the scion has outgrown the stock slightly in several of the trees. These differences are slight, and immaterial at the present time. Whether the difference will ultimately become too great to be satisfactory remains to be determined. These trees were grafted from one to two feet above the ground where the scion more often outgrows the stock than at or below the surface of the ground. The Comice has outgrown the *P. ussuriensis* stock, and in many cases this difference is so pronounced that the union must be considered very unsatisfactory, and it is apparent that eventually the tree will either become seriously stunted or break off at the graft union. Hence, Comice should not be top-worked on *P. ussuriensis.*

As has already been indicated the most desirable tree is one with a resistant trunk and framework as well as a resistant root system. To produce such a tree it is necessary to graft a resistant variety onto the rootstock and later top-work this with the desired commercial variety, as described under *P. calleryana.* Some growers have used the seedlings of *P. ussuriensis* for both root and body stocks. Since many of the seedlings are susceptible to trunk blight and many of them develop an undesirable framework they should not be used for body stocks.

Some of the vigorous, blight-resistant strains of *P. ussuriensis,* however, may prove satisfactory trunk and framework stocks. These should not be used until it has been fully determined that they are perfectly hardy in the locality in which they are to be planted. The winter injury experienced during the past winter on the trunks of some varieties of this species proves that some of them—notably Chieh Li, Hsiang Sui, Hung Guar, and Ta Suan—should not be used as trunk stocks. Certain seedlings of Ba Li Hsiang have proved hardy and vigorous as well as immune to blight, and these are being tested as body stocks and may prove valuable for this purpose. Such strains, of course, must be propagated by budding or grafting.

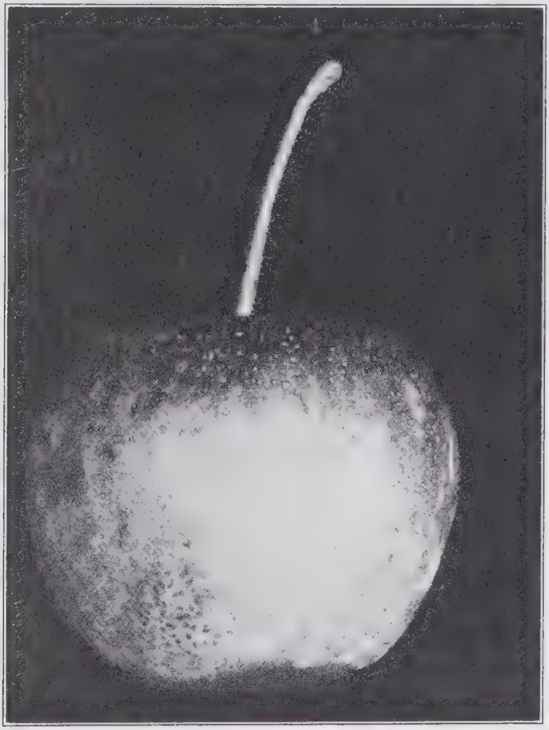

Fig. 33. Fruit of Hung Guar, a cultivated variety of *P. ussuriensis.* Tree immune to blight. Fruit of poor quality.

Until we have further evidence regarding the value of these strains of *P. ussuriensis* as body stocks, it will be safer to use some of the most resistant French or American varieties for this purpose, such as Old Home, Variolosa, and Farmingdale. In our stock orchard most of the Old Home trees have made excellent growth on *P. ussuriensis* rootstocks, part of them being larger than the same variety on French stock, some of them of the same size, and some being smaller. It is unfortunate that the seedlings of even the best varieties of *P. ussuriensis* vary in vigor to this extent. If all of the *P. ussuriensis* seedlings were as strong growers as the most vigorous of them, this would be a highly desirable rootstock. Such uniformly vigorous trees can be obtained in this species only by selecting the most vigorous seedlings in the nursery, and also by propagating selected seedlings from root cuttings as described on page 31 and 33.

**For fruit.** In Manchuria varieties of *P. ussuriensis* are extensively cultivated for their fruit; in fact, the leading varieties of southern and central Manchuria are either pure *P. ussuriensis* or hybrids of this species. There these varieties are very productive and the fruit of some of them is of good quality. The fruit is usually small to medium in size, tender fleshed and juicy, with a spicy, subacid flavor. The best flavored of these varieties in China are Hsiang Sui, Tang Li, Chien Pa, and Man Yuan Hsiang. The following rank as "poor" in flavor: Ba Li Hsiang, Chieh Li, Chiu Tze, Hua Kai, Huang Hsiang Sui, Hung Guar, Lo Suan, Nan Li, Mien Suan, Ping Li, Ta Mo Pan, Ta Suan, and Ta Tou Huang.

Some of these varieties, such as Pai Li, Hsiang Sui, and Tang Li, may prove of value for their fruit in certain parts of the United States where it is difficult or impossible to grow the better flavored American or European varieties. The fruit of most of these, however, is too small to be of commercial importance and cannot compete with the larger and better flavored fruit of the American varieties.

**For breeding purposes.** The writer believes that *P. ussuriensis* will prove more valuable in breeding work than for any other purpose. For many years horticulturists engaged in breeding work have been searching for a blight-resistant pear to be used as one of the parents. Until *P. ussuriensis* was introduced into this country no such blight-resistant variety was known. Furthermore, the earliest introductions of *P. ussuriensis* were all seedlings and produced very small, inferior fruit, identical with the wild fruit produced by this species in the Orient.

Attention has already been called to the fact that several of the varieties belonging to this species are highly resistant to blight and fortunately, some of these are the finest flavored varieties belonging to this species. The most promising of these are Hsiang Sui, Tang Li, and Chien Pa. The fruit of these varieties is small, pear shaped, with tender, juicy flesh and attractive, refreshing, subacid flavor. At this Experiment Station these varieties are being crossed with our best flavored American varieties, such as Bosc, Anjou, Bartlett, and Comice. This work was started in the spring of 1921 and has been very much extended during the past three years. The trees resulting from the 1921 crosses were inoculated with blight in 1924 and 21 percent proved immune. These have not borne any fruit up to the present time. We hope that a few seedlings will result from these crosses which will combine the desirable characteristics of both parents, such as immunity to blight, vigor, productiveness, large size, and fine flavor, as well as good keeping, shipping, and marketing qualities. The writer believes that it is only a question of time when such seedlings will be produced. It is, of course, well known that as soon as one such tree is obtained it can be very rapidly propagated and kept true to type by budding or grafting. It is reasonable to believe that this eventually will be the solution of the pear blight problem. The writer is convinced that the material now available for such breeding work is far superior to any that has heretofore been used by pear breeders.

## PYRUS BETULAEFOLIA

**Native habitat.** *Pyrus betulaefolia* is widely distributed throughout northern and central China. The writer found it in many places, from the Great Wall in northeastern China to the Yangtze river, and from the sea coast to a point one thousand miles inland and at an elevation of four thousand feet. It probably does not extend very far south of the Yangtze river. It has never been reported from any part of Japan or Korea.

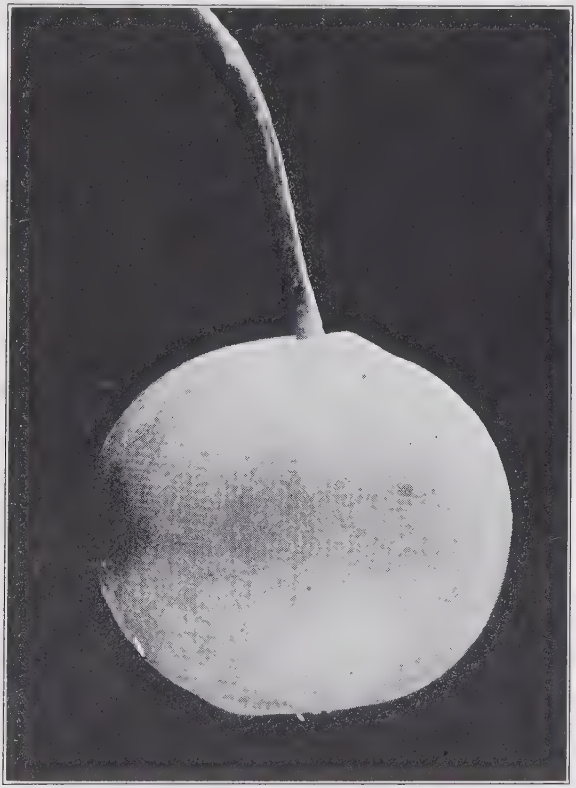

Fig. 34. Fruit of Pai Li, a *P. ussuriensis* hybrid. Finest flavored variety grown in northern China. Tree remarkably resistant to Pear Blight, although not immune. Valuable for breeding purposes.

**Description.** *P. betulaefolia* produces a tree medium to very large in size, usually from forty to sixty feet in height, with a trunk diameter of one to two feet and, rarely, as great as three feet. It is a vigorous but straggly grower, usually with horizontal or drooping branches. Some seedlings are thorny and others thornless. The young shoots are covered with a dense, light gray pubescence. On old trunks the bark is deeply checked and furrowed. The leaves are very characteristic and distinct from those of all other species. They are of medium size, lanceolate, with wedge-shaped base and long, tapering apex, margins coarsely serrate, light grayish-green color, and usually densely covered with grayish pubescence. The blossoms appear late, are very small and are produced in great abundance in dense, pubescent clusters; stamens usually from eighteen to twenty; generally two, and rarely, three pistils. The fruit, which is borne in clusters of from five to ten, is smaller than that of any other species, varying from one-fourth to one-third inch in diameter, round, brown and russeted; flesh greenish, usually free from grit cells, a characteristic readily distinguishing it from that of *P. calleryana.* There are usually two and rarely three seed cells and one or two seeds in each cell. The seeds are very small and dark brown or grayish-black in color.

**Introduction into the United States.** The largest and oldest tree of this species which the writer has been able to locate in this country was planted at the Arnold Arboretum in 1882. This was grown from seed received from Dr. Bretschneider, then living at Peking, China. The tree is approximately thirty feet in height and has a trunk diameter of about one foot. It has proved perfectly hardy at the Arboretum.

Prof. N. E. Hansen, of the South Dakota Experiment Station, imported trees of this species from a nursery in Germany in 1896, and it is a remarkable fact that these trees have proved hardy in that cold climate. Various lots of seed of this species were collected in different places in northern China and sent to this country by the late Frank N. Meyer of the United States Department of Agriculture. A quantity of seed was collected by the writer in northern and central China in 1917 and 1919, and thousands of plants have been grown from these seeds at this Experiment Station. We have found that *P. betulaefolia* hybridizes readily with other species. A large percentage of the seed collected from trees growing in or near orchards containing varieties of *P. ussuriensis* and *P. phaeocarpa* is hybridized with these species. Such hybrid seedlings can be readily distinguished by both leaf and fruit characteristics. Seedlings grown from seeds all of which were collected from one tree often show remarkable variations, due to being hybridized with different varieties or even different species. When pure the seedlings are very uniform and by their light gray color can be distinguished from all other species at a considerable distance.

**Susceptibility to Pear Blight.** The results of the blight inoculation work given in Tables I and II of this bulletin show that *P. betulaefolia* is more susceptible than any other Oriental species except *P. phaeocarpa,* and very nearly as susceptible as *P. communis* in the tips and trunks. This species is far more resistant to blight in the roots than in the tips, and the roots are more resistant than those of the French seedlings. Eighteen of our trees of *P. betulaefolia* proved immune and these trees may become very valuable as the parents of rootstocks, since this species propagates more readily from root cuttings than any other.

**As a stock.** The fruit of *P. betulaefolia* is about the size of a garden pea and of no value, hence this species promises to become of economic importance only as a stock for other pears. In northern China it is extensively used as a stock for the cultivated Chinese varieties and has proved very satisfactory for that purpose.

In our stock orchard the six leading commercial varieties of Oregon are being tested on this species. The trees were grafted from twelve to eighteen inches above the ground and are now six years old. They have made a very satisfactory growth, slightly surpassing in vigor the same varieties on the standard French pear stock. All the Bartlett and Anjou trees and part of the Winter Nelis have made perfect unions with this stock. But part of the Winter Nelis and all the Bosc and Howell trees are slightly larger than the stock just below the union. If this difference never becomes greater than it is at present the union will prove entirely satisfactory. The Comice, as is characteristic of this variety on all stocks when worked above the ground, is considerably larger than the stock. Whether this difference will finally become so great as to impair the rapid flow of sap and ultimately cause the union to become so weak as to prove unsatisfactory remains to be determined. The only safe plan to follow is to graft this variety at or below the surface of the ground. When *P. betulaefolia* is used as a stock the Bosc, Howell, and Winter Nelis should be grafted in like manner for best results. As would be expected, the difference in size between stock and scion is considerably greater in some trees than in others of the same variety, due to the difference in vigor and size of the *P. betulaefolia* seedlings. By selecting only large, vigorous, rapidly growing seedlings of this species for stocks, perfect unions with our commercial varieties will result, especially when worked at the surface of the ground.

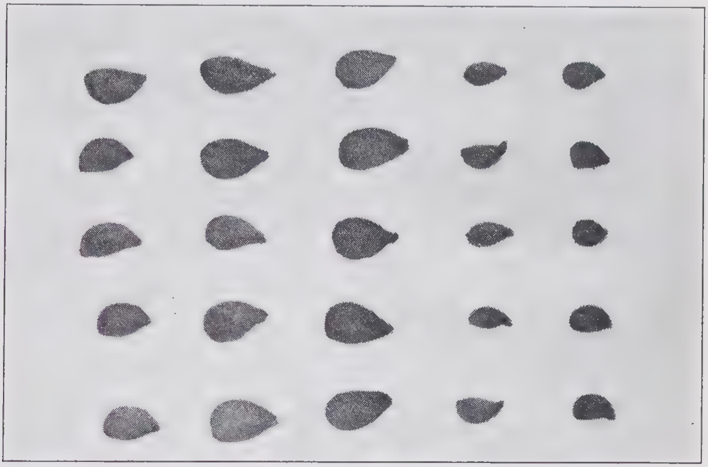

Fig. 35. Seeds of the five leading species of pears. Reading from left to right: *P. communis, P. serotina, P. ussuriensis, P. betulaefolia,* and *P. calleryana.* Note that the seeds of *P. betulaefolia* and *P. calleryana* are very much smaller than those of the other three species.

In another stock orchard Old Home was budded onto *P. betulaefolia* seedlings at the surface of the ground. In this case the unions are all perfect and the trees have outgrown those of the same variety on the French seedlings.

As in *P. calleryana,* the root systems of the different seedlings of this species vary tremendously in habit of growth. Most of them strike deeply into the ground and this enables the trees to endure severe droughts. Part of them have a well branched root system, but a larger percentage than in any other species possesses only long, unbranched tap-roots when not transplanted. By cutting back the tap-roots and transplanting the seedlings when one year old, a well branched root system can be developed in all of them. Such transplanting is more important with *P. betulaefolia* and *P. calleryana* than with any other species.

**Resistance to insects.** *P. betulaefolia* is highly resistant to Pear Woolly Aphis. While it is not immune, the occurrence of this insect on this species is so rare and it is present in such small numbers on any infested tree that it causes no injury whatever.

**Resistance to Leaf Blight.** Near Washington, D. C., *P. betulaefolia* has proved highly resistant to Leaf Blight.[1] In that locality this disease is very abundant on and destructive to the French and Japanese pear seedlings, often defoliating them by mid-summer.

**Soil adaptations.** The writer found this species growing in a great variety of soils in the Orient, varying from coarse sands to heavy clays; and from high, dry, droughty hillsides to low, flat, swampy places. It is really remarkable that a species of pear will endure some of the adverse soil and moisture conditions under which this one is found in northern and central China. In the Ho Nan Province it is often used as a wind and sand break in the sand and alkali regions where very few other shrubs and trees thrive. In a cooperative test now in progress in California, young trees are flourishing in some alkali soils in which all French, Japanese, and *P. ussuriensis* seedlings were killed.

Judging from observations in the Orient and also from the behavior of trees growing on sandy and gravelly spots at this Station, it is likely that this species will endure drought better than any other Pyrus. This is probably due to the habit the roots possess of growing down to a great depth in such soils. It has been observed that the leaves of *P. ussuriensis* often wilt and sunburn on gravelly spots where *P. betulaefolia* flourishes.

It seems remarkable that a tree which can tolerate such droughty conditions should also be able to endure very wet, swampy soils, but this appears to be true. It is, of course, quite possible that we may find great variation within the species and that some seedlings and some root systems will be far better adapted to wet soils than others which may be admirably adapted to very dry soils. If this proves to be the case the two types should be segregated and one propagated for wet and the other for very dry soils.

**Climatic requirements.** This species is found wild from northern China where the winters are dry and very cold, to the Yangtze River in central China, with its mild winter climate, where certain semi-hardy oranges are successfully grown. In the north it extends to the southern limit of *P. ussuriensis.* It has never been reported from central or northern Manchuria, but undoubtedly occurs in extreme southwestern Manchuria. In the United States it has proved hardy at Ames, Iowa, and Brookings, South Dakota.[2] It appears to be perfectly at home in the dry summer climate of Southern Oregon, and is doing well in the hot, dry climate at the Plant Introduction Garden at Chico, California.

Judging from observations made in China and in this country, it appears probable that this species will succeed over a greater area in the United States than any other Chinese species. It may prove as well adapted to the Gulf Coast states as *P. calleryana.* It is unquestionably a remarkable species and should be widely tested in this country.

**For breeding purposes.** Since the fruit of this species is very small and practically inedible, and a high percentage of the trees are susceptible to blight, it offers far less to the pear breeder than does *P. ussuriensis.* It has been used by Professor N. E. Hansen of South Dakota in some of his crosses with American varieties, and since certain seedlings of this species are hardy there, it may prove of value in producing hardy new varieties for very cold climates.

## PYRUS SEROTINA

*Pyrus serotina* is a native of central and western China and central and northern Japan. Some botanists are of the opinion that it was not originally native to Japan, but was introduced there from the eastern part of China. The writer believes that it is a native, since he found the species widely distributed throughout central and northern Japan, where it is wild and appears to be perfectly at home. It is quite probable that the seeds of this species were carried there from China by birds long before the advent of man. The writer found it in the upper Yangtze River Valley, and Mr. E. H. Wilson[5] of the Arnold Arboretum found it in various places in central and western China. It therefore flourishes in regions having a very heavy summer rainfall and comparatively dry winters. The writer has never found it wild in northern China or Manchuria.

**Description.** The tree is a very vigorous grower, attains great size and age, and is very productive. The young shoots have a glossy green bark which becomes darker with age and on the old trunks is deeply furrowed but never checked like that of *P. ussuriensis.*

The leaves are very large, ovate-oblong, with long tapering point, rounded or sub-cordate base, and coarsely setose-serrate margins; when young they are often pubescent, but on most seedlings soon become glabrous. The tree foliates and blooms early in the spring, but not as early as *P. ussuriensis.* The blossoms are borne in loose clusters of five to eight, are large, white, with five and occasionally six to ten large oval petals, and usually eighteen to twenty and rarely twenty-five to thirty stamens, and five pistils.

The fruit is usually round or slightly flattened, from three-fourths to one and one-quarter inches in diameter, of a brownish russet color, and borne on a long stem. The calyx is variable, usually deciduous, but often partly or wholly persistent. The flesh is hard and contains many grit cells, particularly around the core, and has a sweet or insipid flavor, never equalling the finest varieties of *P. communis* or the best varieties of *P. ussuriensis.* The core is five celled with two large dark brown or black seeds in each cell. There is great variation in the character of the calyx. On some trees all of the fruits have a deciduous calyx, while on others the various fruits have from one to five of the lobes persistent. Some botanists hold the opinion that those forms having an entire or partial persistent calyx are hybrids between *P. serotina* and some other species.

**Introduction into the United States.** *Pyrus serotina* was brought to this country earlier than any other Oriental species. The first importation was that of the Chinese Sand pear, obtained in England and brought to this country in 1840 by William Prince of Flushing, New York. Since then it has been brought to this country at various times by sea captains, missionaries, and others. During the past thirty-five years large quantities of seeds and seedlings have been imported into the United States and propagated for stock purposes.

*P. serotina* has been popular with nurserymen in the southern states and on the Pacific Coast. In the South it is usually less susceptible to leaf blight and far more vigorous than the French stock. In the southern states and on the Pacific Coast it is, at this time, more widely used for stock purposes than the French pear. In the northeastern states, more particularly in New York and New England, it is not as popular or valuable as the French stock, due probably to lack of hardiness. This stock is not as hardy as the French, hence should not be used in the colder portions of this country. It has given rise to a number of cultivated varieties which seem to be better adapted to the southern states than any of the European varieties.

**Resistance to blight.** From time to time it has been observed by pear growers, particularly in the southern states, that some of the seedlings of these so-called Japanese pears were much freer from pear blight than the French varieties. The inoculation results reported in Table II show that this is an extremely variable species, ranging from highly resistant varieties to those which are very susceptible. Among all the trees inoculated only four have proved immune in all parts of the tree, although many others have blighted only in the young shoots. It is far more susceptible in trunks and roots than *P. calleryana* and *P. ussuriensis,* only slightly more resistant in the roots than *P. betulaefolia,* but is much more resistant in trunks and roots than the French seedlings.

This species is not as resistant to the Mushroom Root Rot as the French pear stock. The writer has observed a number of trees which were attacked by this disease, and several cases have been reported from the state of California. Hence, this stock should not be used on soils which are known to be infested with Mushroom Root Rot. The fact that *P. serotina* is susceptible to this disease, and also that it is sensitive to wet soils, will eliminate it from many Pacific Coast plantings.

**Resistance to Woolly Aphis.** The Japanese seedlings are far more resistant to Pear Woolly Aphis than the French pear stock. In general, it can be said that this insect is not a serious pest on this stock; occasionally young seedlings are dug in the nursery which are thoroughly infested with Woolly Aphis, but these cases are rare. The species, however, is not nearly as resistant to this insect as *P. calleryana, P. betulaefolia,* or *P. ussuriensis.*

**As a stock.** *P. serotina* has been used as a stock in the United States much longer than any other Oriental species. It has been extensively propagated and distributed, and we now possess evidence relative to its merits as well as its limitations. Up to the present time it has been most satisfactory in the mild climate of the southern states and on the Pacific Coast, and apparently will always be more useful in those regions than in other sections of this country.

The pears which are most widely grown on the Pacific Coast, such as Bartlett, Bosc, Anjou, Winter Nelis, Howell, and Comice, are very easily and successfully propagated on this stock. The buds and grafts unite readily, make a good strong union and the stock maintains the same size as the scion when the union is formed at or below the surface of the ground. These trees are equally as vigorous as those on French pear stock and in some cases more vigorous. Old Home and Variolosa make good unions with this stock and the trees are vigorous, but not equal to those on *P. calleryana.* In our work at this Station it has been demonstrated that practically all of the known species of Pyrus can be propagated on *P. serotina.* All of these species bud readily, make a strong union and grow very satisfactorily on this Japanese stock. The poor stand of buds often obtained on this stock in New York state is probably due to winter injury. Such winter injury was especially abundant at this Station in 1924, when most of the buds of our standard varieties died because a small area on the Japanese seedlings, immediately around the inserted buds, was killed. The remainder of the seedling was not injured. The opening made on the seedling in budding permitted winter injury at this point.

**Soil adaptations.** While *P. serotina* can be successfully grown on a variety of soils, it is not as cosmopolitan as the French stock. As it becomes more widely distributed we are learning that it has certain limitations. On the Pacific Coast it appears to be equally as satisfactory as the French stock on deep, mellow, and well drained soils. On shallow and wet soils it is not satisfactory. Under such adverse conditions the young trees grow vigorously for a number of years, but when the trees are from ten to fifteen years old they become stunted and unsatisfactory. The French and *P. calleryana* stocks will give far better results than the Japanese seedlings on such soils. *P. serotina* will not endure soils containing alkali or an excess of lime. On soils of this character *P. betulaefolia* will prove more satisfactory as a stock.

Whether the trees of our standard American varieties will prove as long lived on this stock as on the French, remains to be determined. This point can be finally decided only after many more years of observation.

The Japanese seedlings usually develop a strong and well branched root system. Some of the seedlings, however, have a tendency to produce two or three prong roots which strike deep into the soil and possess very few lateral roots. This tendency to produce a deep root system is more pronounced than in most of the French seedlings. It is a valuable characteristic on deep, mellow, well drained soils, but is objectionable on shallow soils underlaid with tenacious or tight clay subsoils, or with hard-pan or bed-rock. From this it is evident that the trees should be transplanted in the nursery at least once in order to develop a better branched root system.

**For top-working.** The Japanese seedlings cannot be recommended as trunk and body stocks for top-working purposes. There is too much variation in the seedlings; most of them are exceedingly spiny and few possess a desirable framework for top-working. In other words, the branches do not grow in the upright, spreading manner which makes a clean, vigorous growth at a desirable angle for top-working. Among the hundreds of tested seedlings of this species one has been found which is immune to blight and the framework develops a desirable form. This will be thoroughly tested and if it makes a good union with our cultivated varieties it will prove valuable as a body stock. This type must, of course, be propagated by budding or grafting.

**For breeding purposes.** *P. serotina* crosses readily with the American varieties and will undoubtedly prove of greatest value in the pear breeding work in our southern states. It is one of the parents of Kieffer and related varieties which have proved valuable in the southern states. There it appears to be perfectly at home, because the climatic conditions, at least during the summer months, are similar to those of central China; the tree is much freer from insects and various diseases, and far more productive than the French pears. At present it appears to be the most promising of all the Oriental types for pear breeding in that region. It is probable that in the northern states and on the Pacific Coast *P. ussuriensis* will be of more value for breeding purposes than *P. serotina.*

## MINOR AND DOUBTFUL SPECIES

Five other Chinese species of Pyrus which have shown a fair degree of resistance to blight should be mentioned here. These apparently are not as valuable as the foregoing species, but since they are natives of the Orient and may be confused with the more valuable species by seed collectors, and are not well known in this country, it will be well to enumerate briefly their chief characteristics.

### PYRUS SERRULATA

The type which Mr. Alfred Rehder has designated as *P. serrulata*[5] is a doubtful species. This appears to be a group of hybrids. It will facilitate the discussion in this publication, however, to retain this specific name.

**Description.** As it grows in central China, the type is intermediate between the two species, *P. serotina* and *P. calleryana.* The leaves are very similar to those of *P. calleryana,* but slightly longer. The fruit is brown in color, like the two parent species, but intermediate in size and number of core cells—usually three or four. The seedlings grown from seed collected by the writer in central China are extremely variable, ranging from types identical with *P. calleryana* to those typical of *P. serotina.* In China it has been found only in a region in which both *P. calleryana* and *P. serotina* occur. For these reasons the writer considers this a group of hybrids between these two species. If it is a distinct species it hybridizes very readily with both *P. calleryana* and *P. serotina.*

Mr. E. H. Wilson of the Arnold Arboretum found this type growing in the mountains west and southwest of Ichang in central China, and the species was based on the material which he collected. So far as known at the present time, it is not very widely distributed.

**Inoculation results.** The results obtained from our inoculation work with this species were presented in Table I. These results show as great variation in the seedlings as that displayed in the botanical characteristics. A number of the types are highly resistant, a few immune, and some are very susceptible. Slightly more than 40 percent of the trunk inoculations developed heavy infections. It is therefore far more susceptible than *P. calleryana.*

An interesting type in our collection, belonging to this species, is one which Mr. Wilson introduced as Serrulata No. 479. This type has been propagated by budding, and since it may prove valuable as a body stock the inoculation results have been reported in Table V. At this Experiment Station it has proved a vigorous grower and in leaf and fruit characteristics it is intermediate between *P. serrulata* and *P. betulaefolia.* This tree has been in bearing for five years and has never shown any natural infections, although it is growing in the midst of other varieties which blight readily. This tree has been inoculated many times during the past nine years; most of the inoculations on the trunks and large branches have failed, while the remainder have produced only small superficial bark cankers. Many inoculations made in the tips of young and succulent shoots have been successful, but the infections have always been confined to the small growths, never extending into wood more than one year old. The disease usually extended down the young shoot for only a few inches. This tree has been heavily pruned, is growing on very fertile soil, and has been thoroughly cultivated and irrigated in order to make it as susceptible as possible to pear blight.

Since the seedlings are so variable and a much larger percentage of them are susceptible to blight than in *P. calleryana,* they cannot be recommended as blight-resistant stocks. Some of the immune trees may prove valuable when kept true to type by propagating from root cuttings. Some trees of this species appear promising as trunk and framework stocks. These particular trees are immune to blight and are vigorous growers. Unfortunately, none of our standard varieties have been top-grafted to this type, hence we cannot say whether the union will prove congenial. Serrulata No. 479 makes a very slow growth in the nursery on all the stocks, but grows vigorously when transplanted to the orchard.

**Soil and climate.** In the region in which *P. serrulata* has been found in China the climate is hot and damp in summer and mild and comparatively dry in winter. Just how low the temperature goes during the winter months is not known, but it is probable that it is never lower than zero. At this Experiment Station two-year-old seedlings withstood a temperature of ten degrees below zero without injury, and the species appears to be hardy near Boston, Mass.

Little has been done to determine soil adaptations and requirements of this type. It grows splendidly on a fertile, deep, silty clay loam soil at this Station, and in the mountains of China it was found on a variety of clay and sandy loams. The writer observed it only in the mountains and always on soils that were well drained. It cannot be recommended as a stock for extensive commercial planting until it has been thoroughly tested in an experimental way.

## PYRUS BRETSCHNEIDERI

This form was given specific rank[5] by Mr. Alfred Rehder, and his description was based on a single tree growing at the Arnold Arboretum, which was obtained from seed collected near Peking, China, in 1882.

**Description.** The tree is a vigorous, upright grower with slender and very dark, glossy branches. The leaves are large, elliptical or elliptical-ovate, with acuminate apex, broad wedge-shaped base, and coarsely setose-serrate margins. The fruit is borne on long, slender peduncles, is round, yellow, three-fourths inch in diameter, with a deciduous calyx. The flesh is white, firm, juicy, with few grit cells, and a mild subacid flavor. The core is three or four celled.

The writer is inclined to believe that this is not a distinct species. In his extensive travels in northern China and particularly in the region around Peking, he found only four trees which could be placed in this group. These, however, were in some respects quite distinct from Mr. Rehder's type and from each other. They were similar only in having round or slightly oval fruit, yellow in color, with a deciduous calyx. There was great variation in the leaf, branch and growth characters. The fruits also vary in size, being one-fourth to three-fourths of an inch in diameter.

The writer is strongly of the opinion that these are hybrids, *P. ussuriensis* being one of the parents. One type has leaves closely resembling those of *P. ussuriensis,* and while the fruit is greenish-yellow, like that of *P. ussuriensis,* the size is identical with that of *P. betulaefolia* and like that species has a deciduous calyx. *P. ussuriensis* has probably entered into all of these crosses, but in some cases it is difficult to determine the other parent. In three instances it appears to be *P. betulaefolia.*

The types which the writer found were in the mountains from seventy-five to one hundred miles northeast of Peking. In all instances the trees grew in or near cultivated orchards containing a number of varieties, principally *P. ussuriensis.* In this region *P. betulaefolia* and *P. phaeocarpa* are also found. It is strange that this species is so extremely rare in the locality where it is supposed to be native, while other well established species are very abundant there.

The notes made by the late Frank N. Meyer, explorer for the United States Department of Agriculture show that in his extensive explorations in China he rarely met with this type, and the few trees were isolated specimens.[3] The trees are among the most vigorous of the Chinese pears, but are very shy bearers, thus indicating hybridity.

**Inoculation results.** From 1915 to 1919 our inoculation work with this species was confined to the one form obtained from the Arnold Arboretum. Since the spring of 1920 two of the types collected by the writer in China have been included. This work has been restricted to that portion of the tree above ground, no root inoculations having been made.

The Arnold Arboretum type is not immune to pear blight, but has shown a moderate degree of resistance in the larger wood. The disease has usually appeared only in the smaller shoots and very rarely entered the larger branches. In a few instances, however, infection has been obtained in wood two inches in diameter, and in one case a serious infection occurred in a trunk slightly more than three inches in diameter. No natural infections have been observed in any of these trees. One of the types collected by the writer has shown a very high degree of resistance. Most of the inoculations have failed entirely, and in the small number of successful ones the disease has confined itself to very young shoots. In no instance have we been able to kill a tree one or more years of age.

This type produces fruit a quarter of an inch in diameter, usually two and rarely three celled, and the flesh is free from grit cells. The size of the fruit and number of core cells is typical of *P. betulaefolia,* while the color of the fruit is yellow, in this respect resembling that of *P. ussuriensis.* It is evidently a hybrid between these two species.

**Economic value.** Due to its vigor, freedom from spines and high resistance to blight, one of these types may prove of value as a trunk and framework stock for top-working. Apparently the seedlings are too variable to be desirable for rootstocks. When used for trunk stocks this type should be propagated by budding or grafting on a desirable root system, such as cultivated *P. ussuriensis,* or some other promising species.

## PYRUS OVOIDEA

**Botany.** Mr. Alfred Rehder based this species[5] on one tree at the Arnold Arboretum which was obtained from the Kew Botanical Gardens, as *P. simonii.* The writer never found this type growing wild in China, and does not believe that it is a distinct species. It is probably a subspecies or hybrid of *P. ussuriensis.* It is notable that in the writer's extensive explorations in China, where a careful search was made for it, not one wild tree of this species was found. One of the cultivated pears in southwest Manchuria, Chiu Tze, resembles this form very closely in fruit characters and has leaves which are typical of *P. ussuriensis.*

**Description.** *P. ovoidea* is a very vigorous grower, with long spreading branches. It is free from spines and in that respect differs from the wild type of the well known species of Pyrus. The color of the bark is distinctly yellowish, resembling *P. ussuriensis.* The leaves are very large and thick, ovate-elliptical, with acute apex and coarsely serrate-setose margins.

The fruit, about one inch in diameter, is ovoid in shape, with a long peduncle and persistent calyx. The flesh contains comparatively few grit cells and is white, firm, juicy, and edible. The flavor is sweet but not attractive. The flowers are large and the tree blooms early, closely following *P. ussuriensis.*

**Habitat.** If this is a distinct species, its native home in China is unknown, as the wild type has never been found by any collector. It is undoubtedly a native of the extreme north, since the tree is remarkably hardy in this country, notably as far north as Brookings, S. D. Since it is probably a strain or hybrid of *P. ussuriensis,* its native habitat is doubtless identical with that of the parent species.

**Resistance to blight.** The inoculation results presented in Table I show that this species is very resistant to blight, especially in the older wood. Only 4.8 percent of the trunk infections were classed as heavy, and these were in young trees. This is only a fraction more than the percentage of heavy infections shown by the wild *P. ussuriensis.* It must be borne in mind that all the inoculation work with *P. ovoidea* was done with one type. Most of the trunk inoculations have failed entirely. In some cases small cankers have been produced, but in no instance has a canker completely girdled the trunk or even a branch which was an inch or more in diameter. These cankers have usually been superficial, rarely destroying all of the bark to the sap-wood and in nearly every instance the disease died out naturally and the wound healed over completely from the live tissue underneath. In the young shoots the disease will run from a few inches to two feet, but rarely extends into wood more than one-half inch in diameter, and the type may be regarded as highly resistant.

**Economic value.** This type has not been used as a rootstock, since few seedlings have been available. While it is very vigorous, it cannot be considered desirable for top-working, since the branches do not make a desirable rigid, upright growth. It is quite probable that its greatest value will be for breeding work. Prof. N. E. Hansen of Brookings, S. D., has used *P. ovoidea* in some of his pear breeding work and sent us a hybrid between this species and Clapps Favorite, which he has named Tolstoy. With us this is a vigorous upright grower, with desirable habit of growth, and it has shown a very high degree of resistance to Pear Blight. During our five years of inoculation work with it all of the inoculations on the trunk and most of those on the larger branches have failed. Only two small superficial cankers have developed on branches an inch or more in diameter and in these the disease made comparatively little headway, never reaching the sap-wood. In the young succulent branches the inoculations often failed. In some cases the shoots were killed back a distance of twelve to twenty-four inches, but the infection never extended into wood more than one-half inch in diameter. These trees have been very severely pruned, thoroughly cultivated, on rich soil and are growing among other trees seriously affected by the disease. The tree makes a slow growth in the nursery but becomes vigorous as it grows older in the orchard. No top-working has been done on this hybrid, but judging from its high resistance to blight and its clean, vigorous growth, resembling *P. communis* in some respects, it will probably become valuable as a stock for top-working. We shall thoroughly test it for this purpose in the near future. The fruit produced by this hybrid is very poor in quality.

It should not be inferred from the foregoing that all of the hybrids of this species will be equally resistant to pear blight. Professor Hansen's cross between this species and Parrot, which he has named Gogol, has blighted quite seriously in our inoculation experiments and for that reason has been discarded.

## PYRUS KOEHNEI

This species is a native of the tropical and semi-tropical parts of extreme southern China. It occupies a position there similar to that of *P. calleryana* in central China. As a matter of fact, in tree, leaf, and external fruit characters it is similar to *P. calleryana.* It possesses three or four pistils and core cells, and these are the only characters by which it can be distinguished with certainty from *P. calleryana,* which usually possesses only two and rarely three.

Since this species is a native of extreme southern China, it is practically an evergreen, the old leaves falling just before the new ones appear. Even here in Southern Oregon the leaves remain on the tree and are green all winter. During an average winter this type is not materially injured here, but in severe winters the trees are badly killed back. At a temperature of ten degrees below zero, all of our trees were killed down to the snow line, although the roots remained in perfect condition.

The introduction of this species into the United States was comparatively recent. The only large trees of which the writer has knowledge are five at Oroville, California. These were grown from seeds collected near Canton, China, and shipped to California in 1908 by Mr. G. Compere, of the California State Board of Horticulture. The identity of the species was not known in this country until the writer classified it[7] in the fall of 1915. It has attracted considerable attention because the trees at Oroville have been comparatively free from both blight and Pear Woolly Aphis, while other varieties near these trees have suffered severely from this disease and insect.

In the inoculation work at this Station this species was easily infected in the young wood and the branches were readily destroyed. It has shown a high degree of resistance in the larger wood and especially in the root system. In Southern Oregon it is not a very vigorous grower and is not sufficiently hardy to be recommended.

**Economic value.** Trees of this species were budded in the fall of 1916 with our leading commercial varieties. These have made a vigorous growth, although not equal to those on *P. calleryana.* Up to the present time, the unions have been entirely satisfactory.

*P. koehnei* may prove valuable as a stock in very warm regions and should be thoroughly tested in the southeastern United States and particularly on the Gulf Coast. Judging from Mr. Compere's observations, it will prove valuable on wet soils and on those with a high water table. He found it growing vigorously in swamps near Canton, China, under conditions which would have been fatal to our American pears. This may be due to its shallow root system. The writer has observed that the roots have a tendency to spread out horizontally just below the surface of the ground.

The inoculation results presented in Table I show that this species is not as resistant to blight as *P. calleryana,* but more resistant than *P. serotina* and seedlings of most cultivated varieties of *P. ussuriensis.*

### PYRUS FAURIEI

This is a native of southern and central Korea. In 1917 the writer made a thorough study of its distribution and characteristics in that country. This type appears to be the northern or Alpine form of *P. calleryana.* It is very similar to that species in nearly every respect except size of tree and leaves, which are very much smaller. In fact, the trees are usually mere shrubs or bushes and sometimes grow in thickets. In all respects the fruit is similar to that of *P. calleryana.*

This type is quite variable, some of the seedlings showing a high degree of resistance to blight and others marked susceptibility. It is apparently of little value as a stock, except possibly as a dwarfing form to take the place of the quince commonly used for this purpose.

## RECOMMENDATIONS

The results obtained from our work have been fully presented in this bulletin and the characteristics of all important species and varieties have been discussed. It will, therefore, not be necessary to make any recommendations to those who have read these results and the discussion. Many years must elapse before we can gather sufficient information to enable us to pass final judgment on each species. As additional tests of the various types are made the merits and the limitations of each will become more apparent. The following are merely preliminary recommendations which probably will be modified as further information is accumulated.

**Rootstocks.** At the present time and for several years to come only seedlings will be available in commercial quantities for rootstocks. In each species some desirable and some undesirable seedlings will be found, although certain species produce a much larger percentage of desirable seedlings than others. Hence those species should be selected which produce the highest percentage of suitable seedlings for the particular locality under consideration.

*P. calleryana* appears to be the most desirable stock in localities where root blight is prevalent and the winter climate is mild, as in the Rogue River Valley of Southern Oregon. Until further evidence is available, this species should not be planted where the temperature goes lower than ten degrees below zero. Reliable seed of this species can be easily procured from China.

Seedlings of certain cultivated varieties of *P. ussuriensis,* particularly those of Ba Li Hsiang, are highly resistant to root blight and have made satisfactory rootstocks on deep, mellow, well drained soils. In regions too cold for *P. calleryana* and where root blight is prevalent, the seedlings of these varieties, when grown on such soils, are likely to make the most satisfactory rootstocks. Only the most vigorous of these seedlings should be used. This stock should not be used on heavy wet soils.

In China the supply of seed of the most desirable varieties of *P. ussuriensis* is very limited and difficult to obtain. To be assured of dependable seed of this species America will have to produce its own supply.

The French seedling, *P. communis,* will prove highly satisfactory in regions where root blight and Pear Woolly Aphis are not prevalent, and in such regions it is probably the safest stock to use. It will give better results on very heavy, wet and shallow soils than any other species except possibly *P. calleryana.*

*P. serotina,* the Japanese seedlings, should be planted only where the soil is deep, well drained, and free from Mushroom Root Rot. It will prove unsatisfactory on wet and shallow soils and in cold climates.

*P. betulaefolia* should be used where the soil contains too much alkali for the French or *P. ussuriensis* stock. On such soil, however, our commercial varieties of pears will probably not prove profitable on any stock.

The best stock for the various distinct climatological districts can be determined only by experimentation within these districts.

The most valuable rootstocks are discussed on pages 60-90.

**Trunk and framework stock.** In localities where blight often destroys the trunk and body branches of susceptible varieties, such losses can be largely prevented by top-working on a resistant body and framework stock. The most promising varieties for this purpose which have been thoroughly tested in Southern Oregon are Old Home and Variolosa. These have shown a high degree of resistance to blight and make a strong and desirable union with the leading varieties grown here. Both are hardy in this region, develop a strong, well formed framework, and Old Home is the most vigorous grower in our entire collection. These varieties are budded or grafted on the most suitable rootstock at the surface of the ground. The one-year-old trees are planted in the orchard and grown for at least three years, during which time a well branched and symmetrical framework is developed. They are then top-worked in the branches with the desired commercial variety, as shown in Fig. 25.

Kieffer has been used as a body stock in Southern Oregon, and our leading commercial varieties make an excellent union with it when top-grafting is done on one-year-old wood. This variety, however, is not sufficiently resistant to blight to be employed as a stock. Furthermore, it is subject to winter injury.

Estella is highly resistant to blight in the larger wood and makes a good body stock for Bartlett and Anjou. It is not a congenial stock for Bosc.

Certain other varieties also appear very promising as body stocks and when thoroughly tested may prove equal or even superior to Old Home and Variolosa. Among these are Farmingdale, Tolstoy, Serrulata No. 479, and certain strains of Ba Li Hsiang.

Owing to the great variation in seedlings they should not be used for any portion of the tree above ground.

The most valuable body stocks are discussed on pages 42-48.

The fact should be emphasized that when a susceptible variety like Bartlett is top-worked on a resistant body stock like Old Home the Bartlett part does not become resistant to blight. In other words, the Bartlett portion of the tree will blight just as readily when it is infected as it will on any other stock. The chances of infection, however, are very materially reduced since there is no "hold over" blight in the resistant root and body stock.

## ACKNOWLEDGMENTS

The writer has been assisted in the inoculation work at various times by his former assistant, Mr. A. C. McCormick, and by his present assistant, Mr. R. K. Norris. To these men he wishes to express his appreciation.

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Station Bulletin 215 June, 1925

## Oregon Agricultural College

## Experiment Station

# Phloridzin

## I. THE SIGNIFICANCE OF PHLORIDZIN IN APPLE AND PEAR TISSUE.

## II. THE HYDROLYSIS AND ESTIMATION OF PHLORIDZIN.

By

E. M. Harvey

1885

CORVALLIS, OREGON

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# Phloridzin

By

E. M. Harvey

## I. THE SIGNIFICANCE OF PHLORIDZIN IN APPLE AND PEAR TISSUE

### INTRODUCTION

The almost universal presence of glucosides in plants, and their very diverse and often remarkable constituents, should lead one to suppose that a large amount of functional information relative to these substances must have accumulated. Such an assumption, however, does not appear to be borne out by the facts, for the large portion of the knowledge of glucosides is of a purely chemical nature; the physiological role apparently having received comparatively little attention.

The relatively few physiological studies made have already led to the general belief that many glucosides, or their glucosidal derivatives, must play indispensable roles in vital processes. The fact that there is usually associated with every glucoside an enzyme capable of splitting it is in itself rather significant. Notwithstanding these suggestive leads, the data relative to the function of the commonest glucosides remain very meager indeed. This situation may be illustrated simply by turning to a few of our standard reference books dealing entirely, or in part, with this group. In these books, one reads in the single chapter, or sub-chapter, under the heading, "Physiological function of glucosides," the same brief paragraphs, continually copied from one work to another, with but slight alteration.

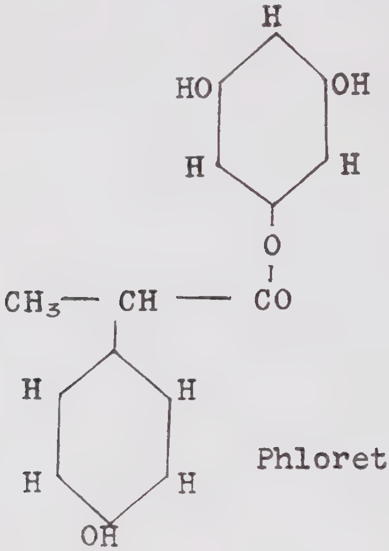
The interest of the writer in the glucoside, phloridzin, of apple tissue, originated several years ago on the occasion of finding, in connection with other chemical analyses, this substance in abundance in certain apple tissue, and being unable to find in the literature anything regarding its physiological function and almost nothing on its specific distribution. No definite work was inaugurated, however, until 1922, following the appearance of a certain paper by Mitra.[9] Since that time the writer has published two papers,[6, 7] containing data on the behavior of phloridzin. The present work is an extension into the same general field.

But before proceeding with the report, a few general remarks about the phloridzin itself might be of interest. According to Wehmer,[10] phloridzin is found principally in the apple and pear tree, but it has been identified also in several other Rosaceae, such as plum, sweet cherry, and probably Spirea, Crataegus and Amelanchier. In so far as can be judged from the information at hand, phloridzin is the dominating glucoside only in the apple and pear tree. Even in the latter, arbutin apparently occupies an important secondary position.

As to the chemical composition, the empirical formula of phloridzin and its first hydroletic products are as follows:

$$\underset{\text{phloridzin}}{C_{21}H_{24}O_{10}} + H_2O = \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{phloretin}}{C_{15}H_{14}O_5}$$

Of the two primary hydroletic products, the most interesting, and probably most significant is phloretin, which itself contains two benzine rings, one of which is phloroglucine, the other possibly hydroquinone.



Phloretin

Phloroglucin has been identified in the free condition in apple bark; and likewise both phloroglucin and hydroquinone have been found in the pear. Hydroquinone is rather abundant in the latter, where it is associated with its own derivative arbutin. Some of the interrelations in the tissue of arbutin and hydroquinone have been tolerably well worked out. (See Czapek.[3]) That substances of such interesting constitutions, and perhaps high potential for influencing vital processes, occur free, or in loose combination with glucose in living tissue, should be regarded as a fact worthy of serious consideration. It seems remarkable that there is so little available information on the physiological functions of the common phenol acids and the glucosides derived from them.

The present work represents a temporary yielding to a curiosity generated through reflection on the above situation, the curiosity being self-justified by the apparent close relation of this subject to the general physiological studies on fruit trees already in hand.

The specific aim of the work was to determine the relation of phloridzin to the rate of growth of shoots, and to study further the distribution of phloridzin within the shoots.

## MATERIAL AND METHOD

The work here recorded was done with apple and pear shoots. The apple was represented by three varieties, Jonathan, Wagener, and Arkansas Black; and the pear by two varieties, Glout Morceau and Bartlett. The shoots were measured, and samples taken for analysis at intervals through the summer, beginning at a very early stage of their development.

**Collection and preservation.** All shoots collected for analysis were gathered in the morning before 8:00 a.m., and the leaves were removed immediately to check loss of water. They were then placed in tightly closed cans and brought into the laboratory for separation into "tip," "middle," and "basal" portions, and determination of fresh weights. The entire time from beginning of each collection to completion of fresh weight determinations was always somewhat less than one hour. The tissue was then placed in bottles; covered with 90 percent alcohol and heated in a water bath for one hour at 70° C. The fresh weights of samples ranged from 20 to 50 grams.

**Dry weight.** When ready to begin analysis, the entire sample was transferred from the bottle to a 10-centimeter evaporating dish, a little hot water being used to aid in the transference. After reduction to "moist-dryness" on steam bath, the dish was placed in vacuum oven and contents dried to constant weight at 85° C. and pressure of 7 to 10 cm. of mercury. The dry weight of the entire sample was then recorded.

**Preparation for extraction.** The entire dried sample was ground to a fine powder in a mill and transferred to a glass-stoppered bottle. Thence samples of 3 to 9 grams were carefully weighed out for extraction.

**Extraction**. The purpose of the extraction was to remove sugars and phloridzin. Either alcohol or hot water might have been employed as solvent, but the latter was adopted for this work. It was found by experience that water 50° to 60° C. was sufficiently "hot" for complete extraction of phloridzin. Each extraction apparatus used was constructed as follows: An opening was blown into the bottom of an ordinary test tube of 2 cm. diameter. The opening at bottom was covered, from the inside, by means of a thimble of copper milk-strainer cloth, and the thimble was filled with a plug of glass wool. This, the extraction tube, was lowered into a closely fitting and packed spiral of copper tubing. During extraction, a continuous stream of water at approximately 65° C. was passed through this coil. The test tube itself was connected at top with a glass tube and rubber stopper, so that hot water (60° to 70° C.) for extraction could be forced through the tissue at a slow and steady rate. The water bearing the extractives dripped from the bottom of the tube into a funnel and 250 c.c. volumetric flask.

The procedure adopted was to transfer the weighed dried sample to a small beaker and there thoroughly saturate it with water to allow opportunity for complete swelling before transferring it to the extraction tube. After transferring the wet tissue to the extraction tube, the apparatus was connected up as indicated. About 230 c.c. water was passed steadily through the tissue, at such a rate that the extraction consumed about 1½ hours.

**Total sugar and phloridzin.** The entire extract was partly cleared with neutral lead acetate and the excess lead precipitated with sodium carbonate. The final volume of extracts became 250 c.c. It should be mentioned that phloridzin is almost insoluble in pure cold water, but if once brought into solution in these apple extracts, containing many organic impurities, it is prevented from crystallizing out, although it may be present in considerable quantities. If solutions are left standing after completion of the clearing procedure, however, phloridzin is very likely to begin to crystallize. In order to avoid this difficulty, the clearing and division of sample for total sugar and phloridzin determinations were carried through as rapidly as possible.

**Total sugars.** A 75 c.c. portion was taken for total sugars, using the official inversion procedure, after which determination of the sugars was made as described in Bulletin 200 of this Station.

**Phloridzin.** A 75 c.c. portion was pipetted into a 250 c.c. Florence flask, the procedure being exactly the same as that described in Bulletin 200, except that the hydrolysis period was changed from 2½ hours to fifteen minutes. The reason for the alteration will be given in Part II of this report.

## EXPERIMENTAL

Certain data published in Station Bulletin 200 showed that not only is phloridzin more abundant at the apex of the shoot, but also during the most actively growing period it decreases there less rapidly than in other portions of the shoot. Thus the data indicated that phloridzin is closely associated with the regions of high metabolic activity; in fact, the possibility of the quantity of phloridzin present being taken as a measure of the degree of that activity suggested itself. In such case, a curve representing the phloridzin content of an organ should parallel a corresponding curve of metabolic activity. Accordingly, in a growing shoot, and especially the tip portion, the phloridzin and the rate of growth curves might be expected to show a general similarity. This latter situation had been suggested from previous findings, and it became the chief aim of the present work to determine the relationship between phloridzin and growth, in so far as observation on the rate of elongation of shoots and variations in their phloridzin content might permit. The results of such observations are presented below.

**Apple.** Shoot-growth records for the apple are given in Table I, but the greater interest will be found in the graphs of growth rate constructed from these data, and superimposed upon the corresponding graphs representing variations of phloridzin in the respective varieties. These graphs are given in Figs. 1, 2, 3. Arkansas Black shoots show plainly a slower rate of growth at the beginning of the season. This slower initial growth rate is rather difficult to demonstrate, and in the present observations a particular effort was made to do so. Unfortunately in this respect, the attempt was a failure for Wagener and Jonathan. Perhaps the observations were too infrequent or they were not begun early enough in the season. In the Jonathan, however, the slower initial rate is apparently very nearly indicated.

The chemical analyses of the apple shoots are presented in Tables III-V, and the graphs representing seasonal phloridzin variations are shown in Figs. 1-3 as previously mentioned. The chemical data show that water and phloridzin and usually total sugars are most abundant in the tip, and least so at the base of the shoots at all times during the

TABLE I. GROWTH OF APPLE SHOOTS, SUMMER 1924.

(Each value the average of 35 to 60 shoots.)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Arkansas Black | Date | May 7 | May 13 | May 19 | June 2 | June 25 | September 15 |
| | Length of shoots, *cm.* | 3.1 | 8.5 | 15.7 | 30.4 | 35.9 | 36.7 |
| | Rate per day, *cm.* | ...... | 0.91 | 1.20 | 1.05 | 0.24 | 0.01 |
| Wagener | Date | May 8 | May 15 | May 28 | June 11 | July 7 | August 10 |
| | Length of shoots, *cm.* | 4.4 | 8.3 | 15.3 | 22.3 | 31.9 | 33.2 |
| | Rate per day, *cm.* | ...... | 0.56 | 0.54 | 0.50 | 0.32 | 0.04 |
| Jonathan | Date | May 6 | May 14 | May 26 | June 17 | ........ | September 19 |
| | Length of shoots, *cm.* | 5.3 | 12.7 | 23.6 | 29.2 | ........ | 32.0 |
| | Rate per day, *cm.* | ...... | 0.92 | 0.91 | 0.30 | ........ | 0.03 |

TABLE II. CHEMICAL ANALYSES OF ARKANSAS BLACK SHOOTS

| Date | Part of shoot analyzed | Water | Total sugars* | Phloridzin* |
|---|---|---|---|---|
| | | % | % | % |
| May 7 | Tip | 76.2 | 2.82 | 7.0 |
| May 19 | Tip | 74.5 | 3.75 | 9.7 |
| | Base | 71.2 | 3.70 | 8.0 |
| June 2 | Tip | 73.5 | 4.08 | 14.1 |
| | Middle | 70.3 | 2.32 | 7.1 |
| | Base | 65.2 | 3.12 | 7.2 |
| June 25 | Tip | 70.0 | 3.50 | 12.5 |
| | Middle | 63.6 | 2.91 | 7.8 |
| | Base | 60.2 | 3.02 | 7.0 |
| Sept. 15 | Tip | 50.4 | 3.13 | 7.7 |
| | Middle | 49.6 | 3.05 | 5.1 |
| | Base | 46.3 | 2.13 | 3.8 |

*Sugars and phloridzin values on dry weight basis in this and the following chemical tables.

TABLE III. CHEMICAL ANALYSES OF WAGENER SHOOTS

| Date | Part of shoot analyzed | Water | Total sugars | Phloridzin |
|---|---|---|---|---|
| | | % | % | % |
| May 15 | Tip | 75.7 | 3.28 | 6.84 |
| | Base | 72.6 | 2.83 | 5.93 |
| May 28 | Tip | 73.1 | 4.15 | 8.48 |
| | Middle | 69.2 | 3.21 | 8.65 |
| | Base | 67.4 | 2.42 | 4.09 |
| June 24 | Tip | 69.7 | 3.56 | 12.20 |
| | Middle | 63.2 | 2.97 | 6.11 |
| | Base | 57.0 | 2.84 | 4.73 |
| Sept. 19 | Tip | 50.4 | 2.54 | 6.73 |
| | Middle | 48.5 | 2.59 | 4.63 |
| | Base | 45.2 | 2.19 | 3.85 |

TABLE IV. CHEMICAL ANALYSES OF JONATHAN SHOOTS

| Date | Part of shoot analyzed | Water | Total sugars | Phloridzin |
|---|---|---|---|---|
| | | % | % | % |
| May 14 | Tip | 73.4 | 2.53 | 6.80 |
| | Base | 72.1 | 3.07 | 6.60 |
| May 26 | Tip | 73.4 | 2.92 | 12.52 |
| | Middle | 70.4 | 2.93 | 7.21 |
| | Base | 66.2 | 2.87 | 6.28 |
| June 17 | Tip | 69.3 | 3.13 | 11.13 |
| | Middle | 68.7 | 2.37 | 6.68 |
| | Base | 59.3 | 2.50 | 5.15 |
| Sept. 19 | Tip | 48.6 | 2.39 | 5.85 |
| | Middle | 47.2 | 2.56 | 4.37 |
| | Base | 45.3 | 2.34 | 3.32 |

growing season; a situation in agreement with the writer's previous findings. The most interesting portion of the shoot is the "tip," since this includes the most active tissues; namely, the growing point and later the developing bud. In the tip of the shoot, phloridzin increases for a time, and then gradually diminishes to the end of the summer. This phloridzin maximum does not exactly coincide in point of time with the growth rate maximum. That is to say, they do not coincide in Arkansas Black shoots, and it is not likely that they would have coincided in Jonathan and Wagener had the characteristic type of growth maxima been demonstrated. The phloridzin maximum lags about two weeks behind the growth rate maximum. Also the growth curve falls much more rapidly than the phloridzin curve. These points will be mentioned again farther on in the discussion.

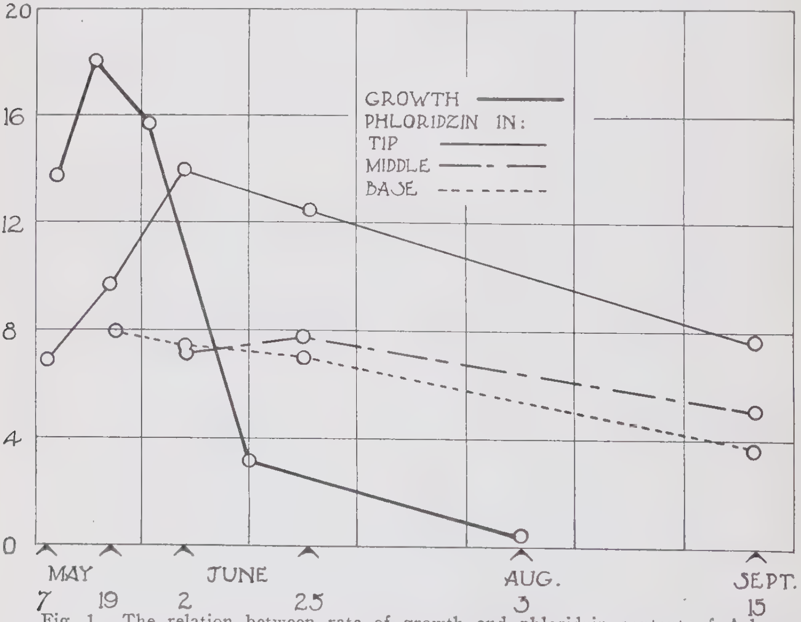


Fig. 1. The relation between rate of growth and phloridzin content of Arkansas Black shoots. Growth rate is in terms of centimeters per day, but multiplied here by 15 to make numerically equivalent to phloridzin percentages.

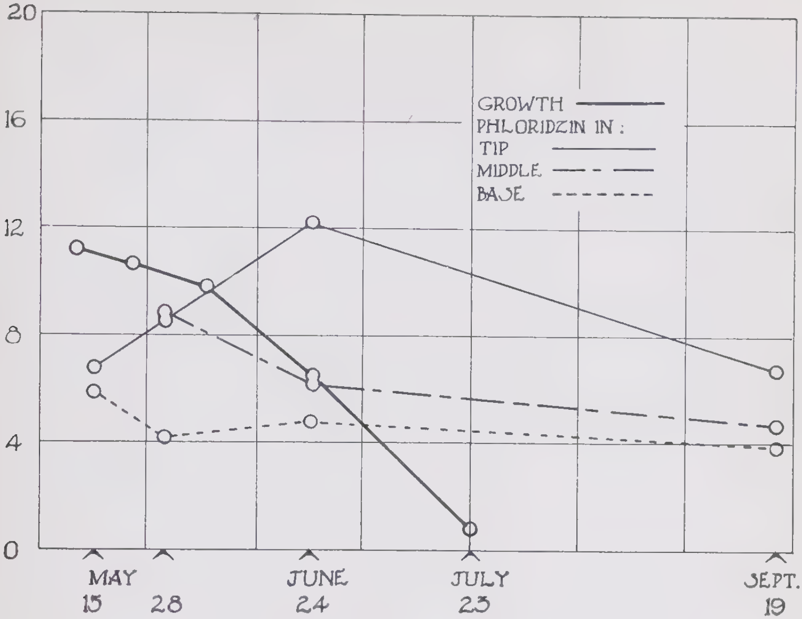


Fig. 2. The relation between rate of growth and phloridzin content of Wagener shoots. Growth rate multiplied by 20. (See legend to Fig. 1.)

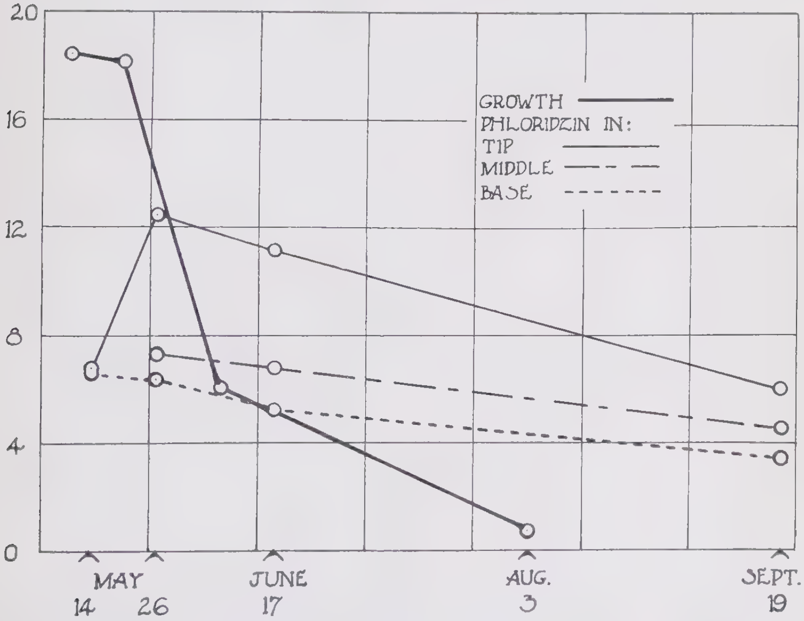


Fig. 3. The relation between rate of growth and phloridzin content of Jonathan shoots. Growth rate multiplied by 20. (See legend to Fig. 1.)

It is interesting in connection with the phloridzin maximum so plainly shown in the present analyses, that this maximum escaped notice in previous work, probably owing to the lateness of the season when the first analyses were done. Nevertheless, a small phloridzin maximum was shown for Grimes (see Bulletin 200, p. 17, Fig. 5), where it was interpreted merely as an experimental anomaly. This illustrates the relative rapidity of the chemical changes taking place in fruit trees early in the spring, and how easily important processes may accordingly be overlooked.

It will be noted in Table I and Figs. 1 - 3 that the middle and basal portions of the shoot do not show any phloridzin maxima, but instead there is a regular falling of phloridzin content through the season.

TABLE V. GROWTH OF PEAR SHOOTS, SUMMER 1924
(Each value the average of about 50 shoots)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Glout Morceau | Date | April 19 | April 25 | May 5 | May 27 | June 23 | Sept. 9 |
| | Length of shoots, *cm.* | 2.8 | 5.2 | 12.4 | 20.4 | 23.3 | 24.9 |
| | Rate per day, *cm.* | ........ | 0.40 | 0.72 | 0.32 | 0.11 | 0.02 |
| Bartlett | Date | ............... | May 12 | May 22 | June 4 | June 24 | Sept. 9 |
| | Length of shoots, *cm.* | ........ | 5.2 | 14.3 | 26.9 | 33.7 | 35.1 |
| | Rate per day, *cm.* | ........ | ........ | 0.90 | 0.97 | 0.34 | 0.02 |

TABLE VI. CHEMICAL ANALYSES OF GLOUT MORCEAU SHOOTS

| Date | Part of shoot analyzed | Water | Total sugars | Phloridzin |
|---|---|---|---|---|
| | | % | % | % |
| April 19 | Tip | 80.0 | 3.94 | 14.2 |
| April 28 | Tip | 79.6 | 3.03 | 16.5 |
| | Base | 79.4 | 2.82 | 14.4 |
| May 9 | Tip | 75.2 | 3.93 | 19.0 |
| | Middle | 74.7 | 2.35 | 16.8 |
| | Base | 73.3 | 2.32 | 14.2 |
| May 27 | Tip | 68.1 | 2.60 | 17.1 |
| | Middle | 67.0 | 2.15 | 13.7 |
| | Base | 66.5 | 2.50 | 8.8 |
| June 23 | Tip | 63.1 | 2.54 | 15.2 |
| | Middle | 59.3 | 2.39 | 7.8 |
| | Base | 58.8 | 2.52 | 6.9 |
| Sept. 9 | Tip | 53.2 | 3.21 | 9.2 |
| | Middle | 50.6 | 2.65 | 6.4 |
| | Base | 50.3 | 2.52 | 5.7 |

TABLE VII. CHEMICAL ANALYSES OF BARTLETT SHOOTS

| Date | Part of shoot analyzed | Water | Total sugars | Phloridzin |
|---|---|---|---|---|
| | | % | % | % |
| May 12 | Tip | 78.1 | 3.63 | 14.2 |
| | Base | 77.0 | 2.23 | 13.6 |
| May 22 | Tip | 75.3 | 5.13 | 18.4 |
| | Middle | 75.1 | 2.77 | 15.7 |
| | Base | 74.7 | 2.13 | 12.2 |
| June 4 | Tip | 72.3 | 3.85 | 20.3 |
| | Middle | 63.8 | 2.21 | 16.4 |
| | Base | 60.1 | 2.85 | 10.4 |
| Sept. 9 | Tip | 54.1 | 2.13 | 9.0 |
| | Middle | 50.4 | 2.07 | 6.9 |
| | Base | 48.8 | 1.89 | 5.2 |

There are no maxima shown by any of the water content curves, but the total sugar curves for the tip of shoots usually show small maxima which agree with those of phloridzin.

**Pear.** Growth records for the two varieties of pear shoots are given in Table II. Both varieties show the slower initial growth rates followed by maxima, which appear in Glout Morceau on May 5, and Bartlett on May 27. The time difference between the appearance of these maxima is due to the fact that the Glout Morceau began growth at least two weeks ahead of Bartlett, although the Bartlett afterwards grew considerably faster than the Glout Morceau. The graphs representing growth are shown in the phloridzin curves in Figs. 4 and 5.

The chemical analyses of the pear shoots show the same general situation as recorded for apple (see tables VI and VII). Pear shoots contain more water, slightly more total sugar, and about twice as much phloridzin as the apple, but their interrelations are practically the same. Phloridzin maxima in the tips are particularly evident early in the growing period. There is also a slight maximum shown for the "middle" region of the Bartlett shoots on June 4. The growth maximum precedes the phloridzin maximum by about one week, and, clearly, there is also a very rapid falling off of growth as compared with phloridzin.

It should be mentioned in regard to the phloridzin figures for pear tissue, that they must be accepted with reservations. Phloridzin,* probably the dominating glucoside in this tissue also, is accompanied by considerable quantities of arbutin. Both these glucosides contain hydroquinone or hydroquinonelike constituents, and they possess other similar physical and chemical properties, so that a separation is rendered difficult. The quantitative method now being employed for phloridzin will, undoubtedly, cause any arbutin present to be broken down and to appear as phloridzin. If this qualification of the phloridzin data for the pear is kept in mind, they are scarcely less interesting, seeing that the vitiation is due to a similar and closely related glucoside.

## DISCUSSION

Many possible functions of glucosides have been suggested. Seeing the great diversity of substances included in this group, wide differences in function might well be expected. Among the different roles assigned to glucosides by various authors may be mentioned the following:

1. As reserve food material.
2. Putting out of action certain harmful by-products of metabolism.
3. Protecting of certain substances, important to metabolism, from too rapid oxidation by tying them up with glucose.
4. As antiseptic and protective agents.

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*Since this manuscript was in press, J. P. Bennett and F. B. Lincoln have reported before the Botanical Society at the ninth annual meeting of the Pacific Division of the A. A. A. S. in Portland, that their findings indicate that arbutin occurs to the complete exclusion of phloridzin in the pear tree. If this be true, all phloridzin figures for the pear in this bulletin may be for arbutin. In such case also they are uniformly too high, because the factor for arbutin would be smaller than for phloridzin.

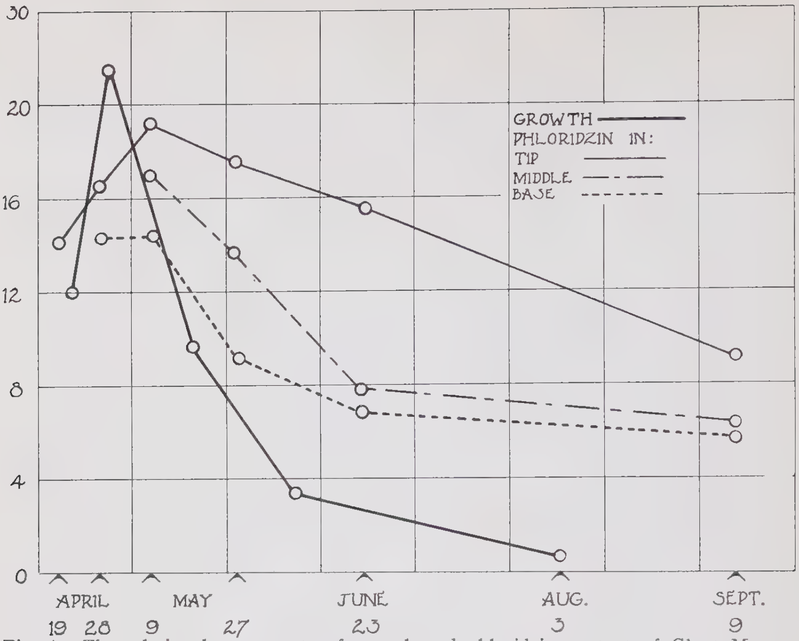

Fig. 4. The relation between rate of growth and phloridzin content of Glout Morceau shoots. Growth rate multiplied by 30. (See legend to Fig. 1.)

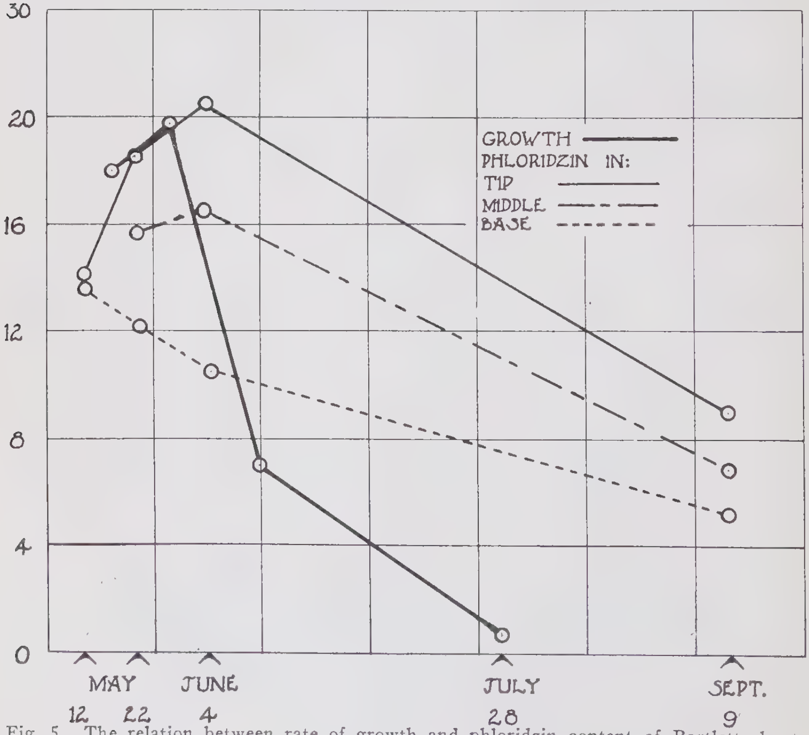

Fig. 5. The relation between rate of growth and phloridzin content of Bartlett shoots. Growth rate multiplied by 20.

5. As activators of growth (harmones) or

6. As accelerators of metabolic processes, particularly that of respiration.

The foregoing list of functions is of such physiological breadth that one may safely assume the function of phloridzin in apple and pear to be included. Although the evidence at hand on phloridzin is meagre, it seems worth while to examine the situation, in an endeavor to determine which of the above functions is being performed.

Phloridzin is most abundant during the season of greatest metabolic activity, that is to say, early summer. This has been shown by Mitra,* who made observations through an entire year. The same situation was indicated in the present report. It was shown also that phloridzin is most abundant at the apex of a growing shoot where growth activity is most rapid. Hence one may assume that phloridzin is closely associated, both with the season of most active growth and with the centers of highest metabolism. This conclusion is in agreement with a general statement concerning glucosides made by Haas and Hill (p. 172).[5] The concentration of phloridzin in the tip region of the shoot appears to be correlated somewhat with the rate of growth. Two points of divergence, however, were noted; first, the phloridzin maximum lags one to two weeks behind the growth maximum; and second, the growth rate falls much more rapidly than the phloridzin content. The above findings seem to point to the following possible roles for phloridzin: (a) as protection against certain phenol acids, originating as by-products of metabolism, or (b) as protection of these phenol acids from too rapid destruction. In the latter case the plant would gain both a storage of them for future use and a means for regulating metabolism. These functions may be practically equivalent. At any rate the role of phloridzin does not appear to be primarily an accelerator of summer growth. For if phloridzin originates as a by-product of active metabolism, and is not an acceleraator of it, one must expect the phloridzin curve to lag behind the growth curve; seeing that the phloridzin content at any moment would be the resultant of a variable rate of synthesis and a rather constant rate of translocation or destruction. This lag, however, may be more apparent than real, because other metabolic processes are going on at the tip of a shoot, some of which may be nearly as energy-consuming as linear extension. It is still possible, therefore, that the phloridzin curve is closely indicative of the total metabolic activities going on at the tip of the shoot. Very little seems to be known concerning the relative energy requirements for cell differentiation, bud formation, and other processes.

The lack of phloridzin maxima, within the observation period, in any part of the growing shoot other than the tip, indicated that, where there is no unusual metabolic activity, the tissues are steadily cleared of phloridzin until the minimum percentage of the dormant season is reached.

There is no reason to believe that growth activity is the only one capable of accounting for phloridzin. It was shown by the writer that if apple shoots are ringed and defoliated, the portion above the ring uses up its carbohydrates very rapidly, and concomitantly there is a rapid increase in phloridzin. (See Bulletin 200, p. 31, Fig. 15.) In such

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*Loc. cit.* Mitra's "Maltose" figures equal phloridzin (see Harvey[6]).

shoots there was neither growth nor photosynthesis, hence, if phloridzin synthesis is related to metabolic activity, some abnormally high rate of respiration in these treated shoots must have been responsible for the recorded increase in phloridzin.

Another point perhaps worthy of consideration in connection with the production of phloridzin, or more particularly, the phenol acids upon which the synthesis of phloridzin must depend, is one coming out of Baly's[1, 2] brilliant studies on photosynthesis. Baly* suggested that the first six-carbon product of photosynthesis would appear in the benzine ring form. If so, he tentatively suggested further, that the next stop could be any one of four, which would result respectively in glucose, fructose, inosite, or phloroglucin. Thus comes a possible explanation for the origin of phloroglucin and hydroquinone, the glucosidal constituents of phloridzin. Assuming Baly's specific suggestion to be true, and assuming also that the four substances mentioned were produced normally in some rather definite ratio to one another, then an accumulation of phloroglucin or its derivatives, at the tip of a shoot would not be hard to understand; especially, on recalling that such an area carries on vigorous photosynthesis and is at the same time a greedy consumer of food material. Under these conditions, glucose and fructose would be used up rapidly for energy and tissue building, leaving the other members to become relatively more abundant. Wherever rapid photosynthesis and respiration, or tissue building, occur simultaneously in close proximity, phenol acids might be expected to accumulate.

It must be added that the indirect or protective function of phloridzin, pointed to by the general evidence at hand, does not eliminate the probability of some important direct function, such as a regulator or an accelerator of growth and other processes. Dr. S. M. Zeller of our department of Botany and Plant Pathology, recently brought to the writer's attention some interesting results which he had obtained from the use of phloridzin in cultures of a fungus which causes cankers on apple and pear trees. He noted an increased growth of this organism in the presence of one percent phloridzin. Furthermore, after examining the writer's data relating to the distribution of phloridzin in apple and pear trees, he states that the most rapid growth of the canker coincides with the season of highest phloridzin content; and finally that the pear is more susceptible than the apple† (cf. phloridzin in apple and pear).

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*Notes taken by the writer on lecture by Professor Baly before the Oregon Branch of the American Chemical Society, Corvallis, 1924.

†Dr. Zeller has kindly consented to make the following brief statement concerning his growth studies: "The growth of *Nectria galligena* Bres., the fungus causing European canker of apple and pear trees, has been tested out on several liquid, nutrient media in order that media with suitable sources of carbon may be chosen for further experiments relative to the physiology of this organism. In preliminary tests Richard's E solution and potato dicoction, both supplemented with one percent phloridzin, proved to be the most desirable media. Greater mycelial growth resulted where this glucoside, supplementing other sources of carbon, was given, than in the same media where the additional source of carbon was a carbohydrate, as glucose, or an alcohol, as mannite. It is still an open question whether the phloridzin acted merely as a stimulant to the growth of N. galligena or whether it served as an additional source of carbon. On the other hand, however, the presence of the glucoside, salacin, in the media retarded mycelial growth of this fungus. Although the experiments as thus far conducted relative to the effect of phloridzin on the growth of the European canker organism are extremely meagre, they open a field for further investigation and some speculation as to the possible influence of this glucoside on infection and canker enlargement. In correlation with the results of Dr. E. M. Harvey's studies, it is at least interesting to observe: (1) that during the periods of greatest growth rate for pear and apple trees, and also the period of greatest phloridzin content of the bark, the canker makes its most rapid enlargement; (2) that the most common place of infection on a pear or apple stem is also the point of highest phloridzin content; and (3) that in Oregon, at least, the canker is much more prevalent on pear than apple bark, the former having a relatively higher phloridzin content."—S. M. ZELLER.

The chief claim of phloridzin on our interest seems to lie in the fact that a substance having two comparatively loosely tied phenol acid constituents, should be present in very active tissue, sometimes to the extent of 20 percent of the total solids and 5 to 6 percent of the fresh weight; and that the more active the tissues, the greater the quantity of phloridzin present. While no direct function in metabolism is now assumed, the conclusion would seem justified that some important indirect roles are played by it, the most probable of which may be taken either as a protection against any harmful accumulation of phenol acids in active areas, or as a means of temporary storage of such phenols for future use. In the latter case some essential direct service may be performed later by the resulting phloridzin as a regulator or accelerator of vital activity, as suggested by the observation of Dr. Zeller referred to above.

## SUMMARY

1. Apple and pear trees contain the greatest quantity of phloridzin in the early summer, coincident with the period of highest metabolic activity. At such times phloridzin may increase to 20 percent of the total solids, or 5 to 6 percent of the fresh weight of the tissue.

2. Pear shoots nearly always contained more water, slightly more total sugars, and about twice as much phloridzin* as the apple. The interrelations of these substances were found to be practically the same in both species.

3. On any given date, phloridzin is most abundant at the tip of the shoot and uniformally less toward the base.

4. In the tip of a shoot, for a relatively short time early in the growing season, phloridzin increases to a maximum, from which point it steadily falls during the remainder of the summer.

5. The "middle" and "basal" portions of a shoot do not show the above type of maximum, for in them phloridzin decreases from the earliest observation to the end of the season.

6. The amount of phloridzin in the tip of a shoot appears to be somewhat correlated with the rate of growth (elongation). The maximum phloridzin content, however, lags one to two weeks behind the apparent maximum growth rate.

7. The observations reported led to the general speculative conclusion that the phenol acids, upon which the synthesis of phloridzin depends, are a sort of by-product of metabolic activity, and that phloridzin serves as a protection against an accumulation of these substances or as a temporary repository of them for future use by the tissue.

8. The possibility of a direct role of phloridzin as an accelerator of vital processes was indicated in a brief reference to some recent, unpublished observations on the effect of phloridzin on growth of fungi by Dr. S. M. Zeller.

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*See qualification, p. 13.

# II. THE HYDROLYSIS AND ESTIMATION OF PHLORIDZIN

## INTRODUCTION

The procedure employed by the writer for the hydrolysis of phloridzin as reported in previous publications[6, 7] was taken over bodily from Darwin and Acton.[4] These authors had said nothing about phloridzin, but recommended the procedure only for the hydrolysis and estimation of maltose in mixtures of other sugars. The writer had occasion to question the accuracy of this method for the determination of maltose in apple tissue, where phloridzin is a normal constituent. On testing the method on pure phloridzin solutions and extracts of apple tissue, it was found to be quite as good a quantitative method for the estimation of phloridzin as for maltose. In fact, it could be used as such in apple tissue, since maltose, if present at all, is in inconsiderable quantities.

The hydrolysis procedure of the Darwin and Acton method requires a so-called "complete inversion" consisting of a 2½ hours' boiling in 2 percent hydrochloric acid.

During the course of numerous analyses, it became apparent that so severe an acid treatment was unnecessary for complete hydrolysis of phloridzin. This led to a special examination of the hydrolysis procedure, for obviously the gentler the hydrolysis could be made, the less would be the destruction of sugars in the mixtures.

## EXPERIMENTAL

**A. Hydrolysis and estimation of phloridzin in extracts of apple tissue.** Some preliminary tests on apple extracts suggested that phloridzin is hydrolyzed very rapidly in boiling 2 percent hydrochloric acid. With this information as a guide, the following experiment was performed: Twenty replicate samples of an apple extract were pipetted into 250 c.c. Florence flasks for hydrolysis. Each of the flasks finally contained: 22 c.c. apple extract; 51 c.c. water, and 4 c.c. concentrated hydrochloric acid (sp. gr. 1.184, giving approximately a 2 percent solution of HCl). It was planned to submit these samples to varying hydrolyzing periods. The hydrolysis was begun by heating the sample over an open flame in such a manner that each came to the boiling point in approximately one minute. After that they were transferred to a Hoskins hotplate and allowed to boil, or simmer, for the hydrolysis period. If that period were longer than 15 minutes, the flask was connected with a reflex condenser. The results of the experiment are given in Table VIII, where the amount of phloridzin was calculated from the increase in reducing power due to the "complete inversion," or hydrolysis, as compared with the reducing power after the official sucrose inversion treatment. It will be noted from Table VIII, and graph I of Fig. 6, that the hydrolysis proceeds extremely rapidly at boiling temperature, so that a maximum value of 58 mg. of phloridzin was reached in 15 minutes. From this time the value falls at such a rate that at the end of the regular 2½ hours' hydrolysis, only 46 mg. of phloridzin was determinable. This fact makes it evident at once that a hydrolysis longer than 15 minutes is undesirable. The sugars are undoubtedly broken down during the long hydrolysis; particularly one suspects sugars such as fructose, probably present originally in the extract. At any rate an advantage in abandoning the 2½ hours' hydrolysis in favor of a much shorter time is obvious.

B. **Hydrolysis of phloridzin in pure solutions.** The purpose of the series of experiments under this heading was to observe the relative effects of: (a) length of hydrolysis, (b) quantity of phloridzin, (c)

TABLE VIII. THE INFLUENCE OF TIME ON THE HYDROLYSIS AND ESTIMATION OF PHLORIDZIN IN EXTRACTS OF APPLE TISSUE, WITH BOILING 2 PERCENT HCl

| No. of sample | Length of hydrolysis | Phloridzin found | Equivalent percentage in original extract |
|---|---|---|---|
| | | *mg.* | % |
| 1 | 30 *sec.* | 9 (?) | 0.15 (?) |
| 2 | 1 *min.* | 18 | 0.29 |
| 3 | 2 *min.* | 32 | 0.51 |
| 4 | 5 *min.* | 51 | 0.81 |
| 5 | 10 *min.* | 57 | 0.90 |
| 6 | **15** *min.* | **58** | **0.98** |
| 7 | 30 *min.* | 55 | 0.88 |
| 8 | 1 *hour* | 54 | 0.87 |
| 9 | 1½ *hours* | 52 | 0.84 |
| 10 | 2 *hours* | 49 | 0.78 |
| 11 | 2½ *hours* | **46** | **0.73** |
| 12 | 3 *hours* | 43 | 0.69 |

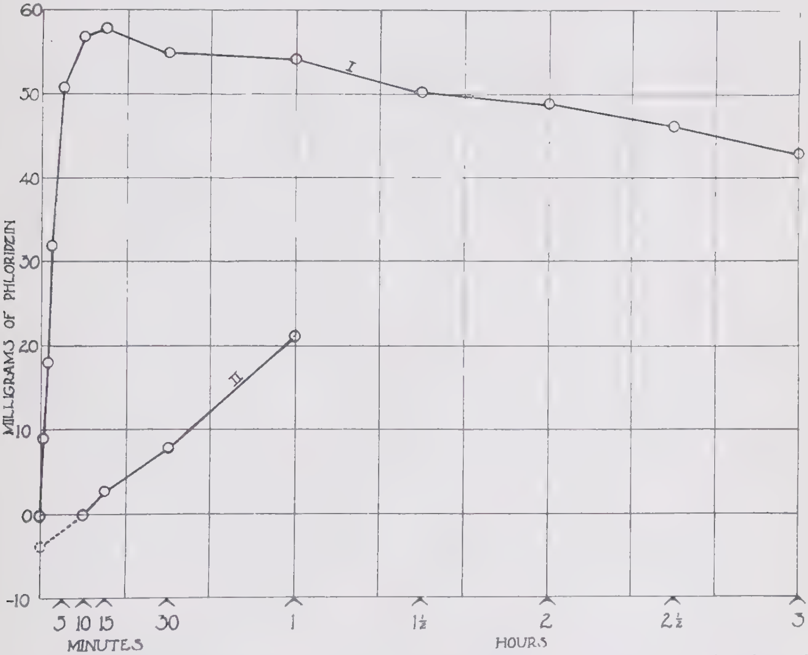

Fig. 6. Hydrolysis of phloridzin in extracts of apple tissue. I. Estimation of phloridzin after hydrolysis with boiling 2 percent HCl. II. The same, but after prolonged (10 minutes plus) exposure to the official inversion solution (i.e., about 2½ percent HCl at 69° C.).

strength of hydrochloric acid, and (d) presence of sucrose (or rather the resulting invert sugar).

The total volume in the hydrolyzing flasks was always 80 cubic centimeters.

A stock phloridzin solution containing 8.673 grams of crystalline phloridzin per litre was prepared. The preceding quantity is equivalent to 8.008 grams anhydrous phloridzin. On account of the insolubility of phloridzin in cold water, the solution was made up to volume at 60° C., and all partitionings of solution were carried out at that temperature.

*Experiment I.* Hydrolysis of 40.1 mg. phloridzin in 2 percent hydrochloric acid (4 c.c. con. HCl).

The results are recorded in the following table.

| Hydrolysis | 5 *min.* | 15 *min.* | 30 *min.* | 2½ *hours* |
|---|---|---|---|---|
| Phloridzin found. *mg.* | 38.1 | 40.1 | 40.3 | 38.0 |

*Experiment II.* Hydrolysis of 100 mg. phloridzin in 2 percent hydrochloric acid.

Results follow in table.

| Hydrolysis | 5 *min.* | 10 *min.* | 15 *min.* | 20 *min.* | 30 *min.* | 2½ *hours* |
|---|---|---|---|---|---|---|
| Phloridzin found *mg.* | 88.6 | 100.0 | 101.0 | 99.1 | 96.7 | 95.4 |

*Experiment III.* Hydrolysis of 150 mg. phloridzin in 2 percent hydrochloric acid.

Results follow in table.

| Hydrolysis | 5 *min.* | 15 *min.* | 30 *min.* | 2½ *hours* |
|---|---|---|---|---|
| Phloridzin found *mg.* | 122.6 | 142.7 | 142.1 | 134.1 |

The three preceding experiments indicate that 40 to 100 mg. of pure phloridzin may be completely hydrolyzed and estimated after a 15 minute boiling with 2 percent hydrochloric acid, but that larger quantities are to be avoided.

The difficulty with the large quantities of phloridzin is due perhaps to a greater destruction of the resulting glucose in excessive concentrations.

*Experiment IV.* Hydrolysis of 100 mg. phloridzin and 1 percent hydrochloric acid (2 c.c. con. HCl).

Results follow in table.

| Hydrolysis | 5 *min.* | 15 *min.* | 30 *min.* | 2½ *hours* |
|---|---|---|---|---|
| Phloridzin found *mg.* | 54.1 | 99.0 | 93.6 | 91.1 |

One percent hydrochloric acid proved about as efficient as two percent for a 15-minute hydrolysis.

*Experiment V.* Hydrolysis of 150 mg. phloridzin in 1 percent hydrochloric acid.

The result of a single observation was as follows: After a 15-minute hydrolysis, only 134.1 mg. phloridzin were found. This suggests that a longer hydrolysis might have been better.

*Experiment VI.* Hydrolysis of 100 mg. phloridzin with 30 mg. sucrose (equivalent to 31.5 mg. invert sugar) in 2 percent hydrochloric acid.

Results follow in table.

| Hydrolysis | 5 *min.* | 15 *min.* | 2½ *hours* |
|---|---|---|---|
| Phloridzin found *mg.* | 82.7 | 95.0 | 67.1 |

*Experiment VII.* As experiment VI except that the concentration of the hydrochloric acid was 1 percent.

Results follow in table.

| Hydrolysis | 15 *min.* | 30 *min.* | 2½ *hours* |
|---|---|---|---|
| Phloridzin found *mg.* | 93.4 | 96.7 | 90.0 |

Experiments VI and VII show that the presence of invert sugar prevents a complete estimation of phloridzin. The difficulty is due likely to the partial destruction of the sugar, especially fructose, during hydrolysis. One percent hydrochloric acid showed but a doubtful advantage over the 2 percent.

The main conclusion to be drawn from the observations on the hydrolysis of phloridzin both in apple extracts and in pure solutions, with and without sugar, is that the time of hydrolysis with 2 percent hydrochloric acid should be reduced from 2½ hours to 15 minutes. It is possible also that some advantage might accrue from the use of 1 percent of hydrochloric acid and a period of 20 to 30 minutes. However, this latter modification is not strongly recommended. More than a year ago, the writer adopted the 15-minute hydrolysis with 2 percent hydrochloric acid (see Part I) and for the present expects to continue the practice.

**C. Hydrolysis of phloridzin by the regular sugar inversion procedure.** It is important to know exactly what effect the sucrose inversion has upon phloridzin, because if any is hydrolyzed by this treatment the phloridzin values will be correspondingly lowered. Not only will the phloridzin values be lowered, but the sucrose or total sugars also will be correspondingly raised. Thus an error might be introduced in all total sugar determinations made upon apple and pear tissue, whether or not the investigator be interested in phloridzin.

In the following tests, the inversion procedure examined is the one which calls for a heating for ten minutes in a water bath at 70° C., with 5 c.c. concentrated hydrochloric acid, in a total volume of 80 c.c.[8]

1. *Sucrose only.* Fifty-cubic-centimeter portions of sucrose solution, each containing 30 mg. sucrose (U. S. Bureau of Standards sample) were carried through the above inversion procedure and the invert sugars determined. The sucrose in each inversion was equivalent to 31.6 mg. of invert sugar and the amount found was 31.7 mg. (which was the average of four inversions and eight determinations).

2. *Sucrose and phloridzin.* Three inversions were made where each flask contained 100 mg. phloridzin and 30 mg. sucrose (equivalent to 31.6 mg. invert sugar). The quantity of sugar found was 32.5 mg., thus indicating that nearly 2 percent of the phloridzin present had been hydrolyzed by this inversion treatment.

3. *Inversion of apple extracts.* In this experiment with apple extract, the time of heating was varied. The extract and the amount used in each sample was the same as previously used in the experiment described under division A above. The time of treating varied from that of the regular period (ten minutes) to one hour.

The results are presented in the table following:

| Length of "inversion" | | 10 *min.* | 15 *min.* | 30 *min.* | 60 *min.* |
|---|---|---|---|---|---|
| Total sugar found, calculated as glucose *mg.* | ............ | 14.9 | 16.1 | 18.3 | 23.6 |
| Increase after 10 minutes *mg.* | ............ | 0 | 1.2 | 3.4 | 8.7 |
| Increase after 10 minutes as phloridzin *mg.* | —4.0* | 0 | 2.9 | 8.2 | 21.1 |

*This value is interpolated from graph II, Fig. 6, and represents, with its sign changed, the phloridzin hydrolyzed by the 10-minute inversion treatment.

The above results show that at the temperature and acid concentration of the regular inversion procedure, phloridzin is gradually hydrolyzed. By referring to graph II, Fig. 6, it will be seen that in one hour 21.1 mg. of phloridzin were broken down. This was about 36 percent of the total 58 mg. previously found (cf. graph I, Fig. 6). Now if graph II is extended downward and back to the axis of ordinates, guided by the general trend of the line, it will strike the axis at a point representing about 4 mg. phloridzin, the quantity probably hydrolyzed during the official 10-minute inversion period. If this deduction is correct, the apple extract under observation actually contained nearer 62 mg. of phloridzin than the 58 mg. recorded; that is to say, the inversion treatment introduced an error in the present case of more than 6 percent. While the writer is inclined to believe this estimated error too large, the experiment nevertheless strongly indicates that an error is always introduced into phloridzin determination by the inversion procedure, although in any given series it may be fairly allowed for. But the above situation has a

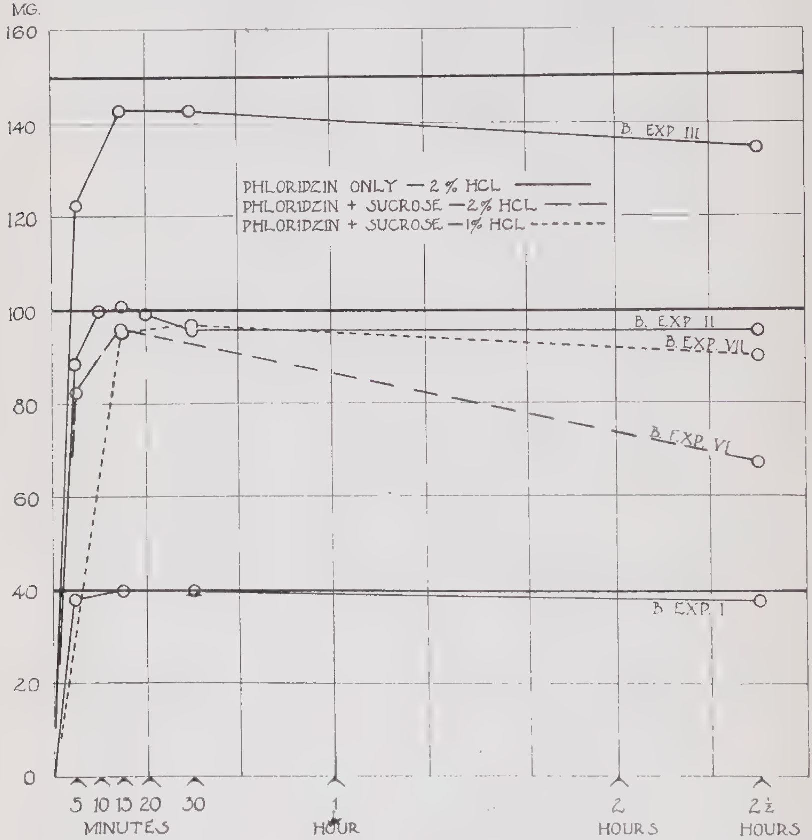

Fig. 7. Graphs showing the hydrolysis and estimation of 40,100 and 140 mg. phloridzin under different conditions.

greater significance in connection with the determining of total sugars in apple and pear tissue. For it means that some phloridzin is being hydrolyzed during the inversion treatment, accordingly augmenting the total sugar values. Also until the behavior of arbutin is better known, an additional caution, for a similar reason, should be exercised when determining total sugars, etc., in pear tissue.

Other similar methods of inversion such as the same at room temperature for 24 hours, or with citric acid, might better avoid the hydrolysis of phloridzin. Certainly inversion by invertase solution could be expected to eliminate any error of this kind, either for total sugar or phloridzin estimations.

## CONCLUSIONS

1. In the estimation of phloridzin, it should be arranged that the quantity hydrolyzed will be within a range of 40 to 100 milligrams.

2. The time of hydrolysis with 2 percent hydrochloric acid should be reduced from 2½ hours to 15 minutes. But with 1 percent hydrochloric the hydrolysis should be 20 to 30 minutes. The weaker acid, however, is not definitely recommended.

3. The inversion procedure most frequently employed (i. e., 10 minute treatment at 70° C. with 5 c.c. con. HCl) introduces an error into both total sugars and phloridzin determination in apple and pear tissue owing to the slight hydrolysis of phloridzin. Inversion by an invertase solution would therefore appear on *a priori* grounds to be the better procedure in dealing with apple and pear tissues. In any case using the regular inversion, great care should be exercised to keep the condition extremely uniform throughout any given series of analyses.

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Station Bulletin 216 June, 1925

## Oregon Agricultural College

## Experiment Station

# The Control of Core Breakdown in Pears

By

HENRY HARTMAN

CORVALLIS, OREGON

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## SUMMARY

(1) The development of core break-down is undoubtedly closely related to the time of picking. In all the tests and observations made, only the fruit harvested after its best picking time became affected.

(2) It is fairly certain that core break-down can be controlled by picking at the proper time and that this can be done without sacrifice of either tonnage or quality.

(3) Storage seems to have but little effect upon the development of core break-down. The amount of disease that ultimately develops does not seem to be influenced by either the kind of storage or the length of the storage period.

(4) The pressure tester, already described in the literature of this Station, again proved to be a reliable indicator of maturity in pears, and at this time appears to be the most effective weapon in the control of core break-down.

(5) Core break-down has generally been controlled and pears have developed good quality when picking has been done within the following ranges of pressure: Bartlett, 35 to 25 pounds; Comice 20 to 18 pounds; Anjou 24 to 19 pounds; Winter Nelis 28 to 24 pounds; Willamette Valley Bosc, 30 to 27 pounds; Rogue River Bosc, 24 to 20 pounds.

# The Control of Core Break-down in Pears

By

HENRY HARTMAN

## INTRODUCTION

To the investigator of plant diseases the physiological troubles of pome fruits present a unique and baffling problem. In spite of much careful research by qualified workers not a great deal has come to light concerning this group of abnormalities. It is true that the nature and control of apple scald and one or two similar disorders are now pretty well understood, but such functional troubles as bitter pit, corky core, dry rot, pear scald, Jonathan spot and others, must still be classed in the category of unsolved difficulties.

**Nature of core break-down.** As the name implies, core break-down is essentially a disease affecting the core area of pears. It is generally a storage trouble, making its appearance as the fruit approaches prime eating condition. In very severe cases, however, it may be found in fruits that are still firm and green on the outside. Affected specimens are occasionally found in fruits still attached to the tree. The disease may be confined to the region of the seed cavity (Fig. 1), or it may extend to the entire core and surrounding portions of the fleshy torus. In its incipient form, the disease is characterized by a soft and watery condition of the affected tissue. Later this is accompanied by a brownish or black discoloration, and a foul odor is generally present during the final stages. In severe cases rapid break-down of the entire fruit occurs.

Thus far, it has not been possible to attribute core break-down to the work of a living organism. Apparently it is a physiological trouble.

**Terminology.** Various names have been applied to this disease by different authors. Several of these, however, are inappropriate and should be discarded. The term "core rot" found in the literature, is undesirable since the disease has not been associated with a specific organism. Such terms as "internal browning,"[1] "brown heart,"[2] and "internal break-down,"[3] have previously been applied to other physiological troubles of pome fruits, and hence cannot rightfully be used here. Of all the designations suggested, the name "core break-down" appears to be the most appropriate and is used throughout this bulletin.

**Distribution.** Although core break-down seems to be more serious in some localities than in others, the trouble is more or less common to all pear regions. Hedrick reports its presence in New York.[4] Drain finds it in the pears from Massachusetts,[5] while Overholser and Latimer recognize it in California.[6] So far as the Pacific Northwest is concerned, no district where pears are raised is known to be entirely free from it.

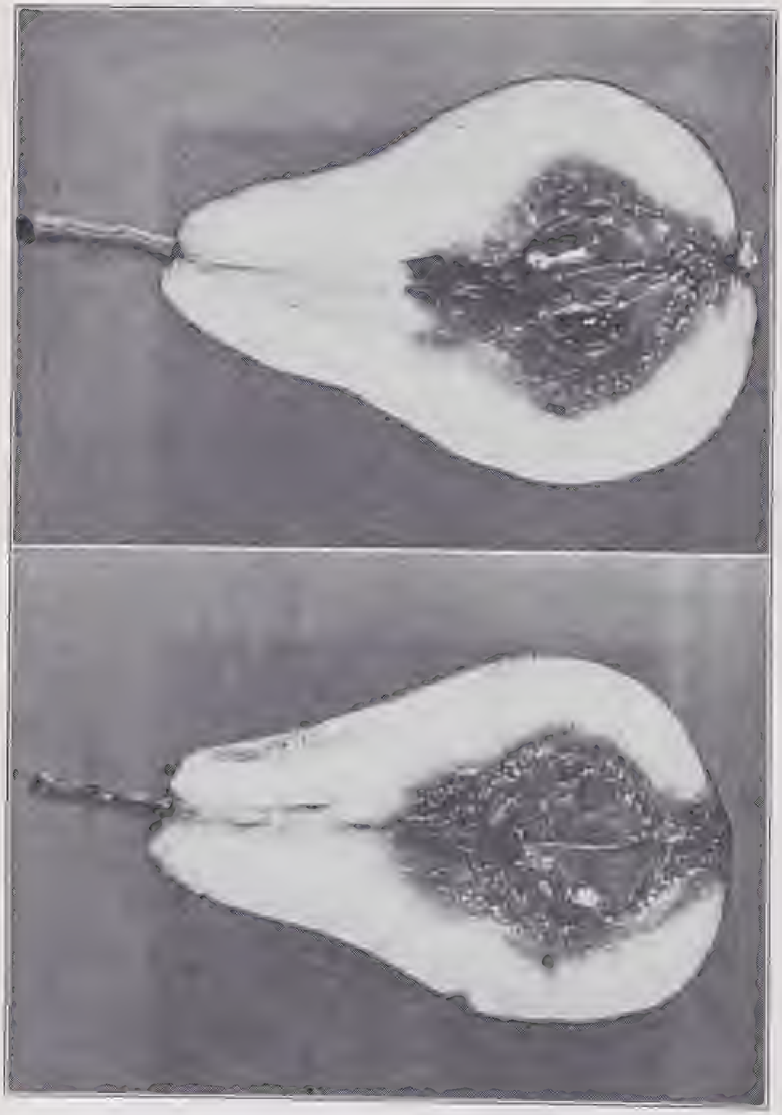

Fig. 1. Typical core break-down in Bosc pears.

**Variety susceptibility.** Apparently most varieties of pears are subject to core break-down. It is clear, however, that some sorts are much more susceptible than others. Hedrick mentions Clairgeau, Clapps Favorite, Doyenne Boussock, Early Harvest, Guyot, Jargonelle, Le Conte, Madeline, and Sudduth, as being readily susceptible in New York. Of the principal varieties grown in Oregon, Bosc, Comice, and Clapps Favorite are very frequently affected. Bartlett appears to be slightly less susceptible, while Anjou and Winter Nelis are fairly resistant.

**Economic importance.** As already indicated, core break-down usually makes its appearance as the fruit approaches prime condition. The average grower, therefore, rarely sees the effects of the disease and does not realize its importance. Although exact figures are not available, it is known that a heavy loss results from core break-down each year. Records show that the loss from this disease may vary from nothing to as much as 90 and 100 percent. The loss from this cause in the pears from a certain Willamette Valley orchard last year was approximately 80 percent. Cannerymen, in particular, frequently sustain heavy losses from this trouble.

## EXPERIMENTAL

Casual observations have suggested that the degree of maturity which the fruit has attained when picked exerts considerable influence upon the development of core break-down, and that perhaps this trouble can be controlled by harvesting at the proper time. Even though this be true, however, considerable specific information is necessary before recommendations can be made. The range of susceptibility for the different varieties must be ascertained, the effects of time of picking on the dessert and keeping quality must be known, and a method for determining maturity must be perfected. Information relating to these phases was furnished by the experiments on pear harvesting and storage which have been in progress at the Oregon Experiment Station since 1917 and by field observations over a period of years in the various pear districts of the Pacific Northwest.

**Time of picking in relation to core break-down.** To gain more information on the relation of time of picking to the development of core break-down, experiments were conducted during the seasons of 1923 and 1924. Representative lots of Bartlett, Anjou, Comice, Bosc, and Winter Nelis were gathered at intervals of 3 to 5 days during the season of maturity. As many as 11 separate pickings were made in some cases. To reduce the probability of environmental difference as much as possible, all the lots of each variety were taken from a single tree. Pressure test determinations were made and the fruit of each lot was placed in common storage at a temperature of 66° F. and a relative humidity of 80 to 86 percent. It was found that all varieties ripened readily under these conditions. To simplify matters, calculations in each case were made on the basis of 100 specimens. Tables I, II, III, and IV give the data obtained in these tests.

**Kind and manner of storage in relation to core break-down.** In the course of the experiments on pear handling, various methods of storage

TABLE I. TIME OF PICKING IN RELATION TO THE DEVELOPMENT OF CORE BREAK-DOWN IN BARTLETT PEARS
(1923 results)

| Lot number | Date of picking and storing | Pressure test | Temperature of storage room | Relative humidity of storage room | Date of prime condition | Number of days to attain prime condition | Amount of core break-down | Condition |
|---|---|---|---|---|---|---|---|---|
| | | *lbs.* | *°F.* | % | | | % | |
| 1 | 8/18 | 38.3 | 66° | 80-86 | 9/2 | 15 | 0 | Juicy, but slightly astringent, and lacking in sweetness. Waxy and slightly aromatic. |
| 2 | 8/20 | 37.2 | 66° | 80-86 | 9/3 | 14 | 0 | Juicy, but slightly astringent and lacking in sweetness. Waxy and aromatic. |
| 3 | 8/24 | 35.5 | 66° | 80-86 | 9/6 | 13 | 0 | Juicy and fairly sweet. Quality better than that of previous lots. Good waxy appearance. Aromatic. |
| 4 | 8/29 | 33.0 | 66° | 80-86 | 9/8 | 10 | 0 | Juicy and sweet. Quality better than that of previous lots. Good waxy appearance. Aromatic. |
| 5 | 9/1 | 31.5 | 66° | 80-86 | 9/10 | 9 | 0 | Juicy and sweet, with full Bartlett quality. Good waxy appearance. Aromatic. |
| 6 | 9/7 | 28.1 | 66° | 80-86 | 9/15 | 8 | 0 | Juicy and sweet, with full Bartlett quality. Good waxy appearance. Aromatic. |
| 7 | 9/11 | 26.0 | 66° | 80-86 | 9/19 | 7 | 0 | Slightly less juicy than previous lots, but of good quality. Good waxy appearance. Aromatic. |
| 8 | 9/14 | 24.8 | 66° | 80-86 | 9/20 | 6 | 5 | Less juicy than previous lots. Sweet, but more or less insipid. Good waxy appearance. Aromatic. Core break-down not serious. |
| 9 | 9/18 | 23.1 | 66° | 80-86 | 9/22 | 4 | 60 | More or less dry and insipid. Good waxy appearance. Aromatic. Core break-down quite serious. Not marketable as first-class fruit. |

TABLE II. TIME OF PICKING IN RELATION TO THE DEVELOPMENT OF CORE BREAK-DOWN IN COMICE PEARS
(1923 results)

| Lot number | Date of picking and storing | Pressure test | Temperature of storage room | Relative humidity of storage room | Date of prime condition | Number of days to attain prime condition | Amount of core break-down | Condition |
|---|---|---|---|---|---|---|---|---|
| | | *lbs.* | °*F.* | % | | | % | |
| 1 | 9/17 | 25.7 | 66° | 80-86 | 11/9 | 53 | 0 | Juicy but astringent and lacking in sweetness. Not waxy. Not aromatic. Not marketable as first-class fruit. |
| 2 | 9/21 | 24.3 | 66° | 80-86 | 11/8 | 46 | 0 | Juicy but astringent and lacking in sweetness. Not waxy. Not aromatic. Not marketable as first-class fruit. |
| 3 | 9/25 | 23.0 | 66° | 80-86 | 11/7 | 43 | 0 | Juicy, but still somewhat astringent and lacking in sweetness. Not waxy. Not aromatic. Quality still inferior. Not marketable as first-class fruit. |
| 4 | 9/28 | 21.6 | 66° | 80-86 | 11/7 | 41 | 0 | Juicy, but still lacking in sweetness. Somewhat waxy. Slightly aromatic. Fair in quality. |
| 5 | 10/1 | 19.1 | 66° | 80-86 | 11/4 | 35 | 0 | Juicy, sweet and of fairly good quality. Somewhat waxy. Slightly aromatic. |
| 6 | 10/5 | 18.2 | 66° | 80-86 | 11/3 | 28 | 0 | Juicy and sweet, with full Comice quality. Good waxy appearance. Aromatic. |
| 7 | 10/9 | 18.2 | 66° | 80-86 | 11/3 | 25 | 5 | Juicy and sweet, with full Comice quality. Good waxy appearance. Aromatic. Core break-down confined to seed cavities. Not serious. |
| 8 | 10/13 | 17.3 | 66° | 80-86 | 11/2 | 20 | 31 | Less juicy than previous lots. Sweet and of fairly good quality. Core break-down somewhat serious. Not marketable as first-class fruit. |
| 9 | 10/19 | 16.5 | 66° | 80-86 | 11/1 | 13 | 100 | Much less juicy than previous lots. Sweet, but more or less insipid. Core breakdown very pronounced. Fruit went down rapidly. Not marketable as first-class fruit. |

TABLE III. TIME OF PICKING IN RELATION TO THE DEVELOPMENT OF CORE BREAK-DOWN IN BOSC PEARS (1923 results). (Willamette Valley Bosc)

| Lot number | Date of picking and storing | Pressure test (pared specimens) | Temperature of storage room | Relative humidity of storage room | Date of prime condition | Number of days to attain prime condition | Amount of core break-down | Condition |
|---|---|---|---|---|---|---|---|---|
| | | *lbs.* | *°F.* | % | | | % | |
| 1 | 9/12 | 28.7 | 66° | 80-86 | 10/1 | 18 | 0 | Of good color and texture. Full Bosc quality. Held up well after maturity. |
| 2 | 9/17 | 27.3 | 66° | 80-86 | 10/9 | 22 | 0 | Of good color and texture. Full Bosc quality. Held up well after maturity. |
| 3 | 9/22 | 26.4 | 66° | 80-86 | 10/11 | 19 | 30 | Of good color and texture. Full Bosc quality. Core break-down confined largely to seed cavities. Not serious. |
| 4 | 9/25 | 25.2 | 66° | 80-86 | 10/13 | 18 | 63 | Of good color. Core break-down much more pronounced. Quality affected somewhat. |
| 5 | 9/29 | 23.9 | 66° | 80-86 | 10/15 | 16 | 100 | Of good color. Core break-down pronounced. Fruit went down rapidly after maturity. Not marketable as first-class fruit. |
| 6 | 10/2 | 21.6 | 66° | 80-86 | 10/17 | 15 | 100 | Of good color. Core break-down pronounced. Fruit went down very rapidly. Not marketable. |
| 7 | 10/5 | 20.3 | 66° | 80-86 | 10/18 | 13 | 100 | Core break-down very pronounced. Fruit broke down before full maturity was reached. Not marketable. |
| 8 | 10/13 | 20.1 | 66° | 80-86 | 10/24 | 11 | 100 | Core break-down very pronounced. Fruit broke down before full maturity was reached. Not marketable. |

TABLE IV. TIME OF PICKING IN RELATION TO THE DEVELOPMENT OF CORE BREAK-DOWN IN BOSC PEARS
(1924 results.) (Willamette Valley Bosc)

| Lot number | Date of picking and storing | Pressure test (pared specimens) | Temperature of storage room | Relative humidity of storage room | Date of prime condition | Number of days to attain prime condition | Amount of core break-down | Condition |
|---|---|---|---|---|---|---|---|---|
| | | *lbs.* | *°F.* | | % | | % | |
| 1 | 8/23 | 31.7 | 66° | 80-86 | 9/13 | 21 | 0 | Juicy, but lacking a little in sweetness and character. Of good color and texture. Held up well after maturity. |
| 2 | 8/27 | 29.3 | 66° | 80-86 | 9/18 | 21 | 0 | Juicy and fairly sweet. Of good color and texture. Held up well after maturity. |
| 3 | 8/30 | 28.8 | 66° | 80-86 | 10/1 | 31 | 0 | Juicy and sweet, with full Bosc quality. Of good color and texture. Held up well after maturity. |
| 4 | 9/3 | 27.3 | 66° | 80-86 | 10/3 | 30 | 0 | Juicy and sweet, with full Bosc quality. Of good color and texture. Held up well after maturity. |
| 5 | 9/8 | 26.0 | 66° | 80-86 | 10/12 | 34 | 6 | Juicy and sweet, with full Bosc quality. Of good color and texture. Held up well after maturity. Core break-down not objectionable. |
| 6 | 9/12 | 25.1 | 66° | 80-86 | 10/12 | 30 | 33 | Juicy and sweet, with full Bosc quality, of good color and texture. Held up fairly well after maturity. Core break-down serious in a few specimens. |
| 7 | 9/16 | 25.2 | 66° | 80-86 | 10/13 | 27 | 62 | Juicy and very sweet. Of good color and texture. Went down quite rapidly. Core break-down quite serious. Not marketable as first-class fruit. |
| 8 | 9/20 | 24.0 | 66° | 80-86 | 10/12 | 22 | 91 | Less juicy than previous lots. Very sweet. Went down rapidly. Core break-down serious. Not marketable as first-class fruit. |
| 9 | 9/25 | 21.6 | 66° | 80-86 | 10/16 | 21 | 100 | Less juicy than previous lots. Went down rapidly. Core break-down developed when pears were still firm on the outside. Not marketable. |
| 10 | 9/30 | 20.1 | 66° | 80-86 | 10/17 | 17 | 100 | Core break-down developed when pears were still firm on the outside. Went down rapidly. Not marketable. |
| 11 | 10/4 | 19.2 | 66° | 80-86 | 10/19 | 15 | 100 | Core break-down developed when pears were still firm on the outside. Went down very rapidly. Not marketable. |

have been under observation for several years and considerable data bearing upon the relation of kind and manner of storage to core break-down have accrued. During the season of 1924, a rather comprehensive storage test of Willamette Valley Bosc was conducted, which also gave considerable information concerning this factor. In this test, three separate pickings were made, the first on September 2, the second on September 9, and the third on September 19. One-half of the fruit in each case was immediately placed in cold storage at a temperature of 32° F. and a relative humidity of 80 to 85 percent. The remaining portion of each picking was subjected to a "delay" of ten days and then was placed in cold storage with the other lots. Altogether 30 boxes of pears were used. Dating from the time of storage a box from each lot was removed at intervals of twenty-five days and allowed to ripen at a temperature of 66° F. and a relative humidity of 80 to 85 percent. The length of the cold storage period for each lot, in other words, varied from 25 to 125 days.

It was thought that a test of this nature might be of value because (1) it would afford a means of comparing core break-down development in cold and common storage, (2) it might yield information relating to the effects of immediate and delayed storage on the disease, and (3) it might show whether or not there is a relationship between the development of the disease and time in storage. Tables V and VI give the data obtained in this phase of the work.

## CONCLUSIONS

From the data presented here and elsewhere, the following conclusions regarding the control of core break-down appear to be justified:

**Core break-down can be controlled by picking at the proper time.** Undoubtedly there is a close correlation between time of picking and the development of core break-down. In all the tests and observations made, only the fruit picked beyond the optimum picking time became affected to any extent. That picked at the beginning of the harvest period, or even past mid-season, remained practically free from the disease. Growers who habitually harvest their pears in due season seldom suffer loss from this cause. Not only can the disease be controlled by picking at the proper time, but it is certain that this can be done without sacrifice of either quality or tonnage.

Apparently, the later the time of picking the more pronounced the disease becomes. Pears picked just at the border line of over-maturity usually show only a trace of core break-down and this only as they become fully ripe. Those picked very late, on the other hand, become affected while still green on the outside, the trouble soon spreading to the entire core area. Early break-down of the specimens usually occurs in such cases.

**Length of the proper picking season varies.** The length of the proper picking season for pears, that is, the length of the period during which pears can be picked without danger of immaturity at one extreme and core break-down at the other, varies considerably with different varieties and with different localities. In all cases, however, the season appears to be sufficiently long to afford ample time for harvesting.

TABLE V. THE RELATION OF TIME OF PICKING AND TIME IN COLD STORAGE TO THE DEVELOPMENT OF CORE BREAK-DOWN IN BOSC PEARS

(Immediate cold storage) (Willamette Valley Bosc)

| Lot number | Pressure test (pared specimens) | Date of picking | Date of cold storage | Box number | Date of removal from cold storage | Number of days in cold storage | Date of prime condition | Number of days to attain prime condition out of cold storage | Amount of core break-down |
|---|---|---|---|---|---|---|---|---|---|
| | *lbs.* | | | | | | | | % |
| 1 | 27.7 | 9/2 | 9/2 | 1 | 9/26 | 25 | 10/9 | 13 | 0 |
| | | | | 2 | 10/21 | 50 | 11/7 | 17 | 0 |
| | | | | 3 | 11/15 | 75 | 12/3 | 18 | 0 |
| | | | | 4 | 12/10 | 100 | 12/22 | 12 | 0 |
| | | | | 5 | 1/4 | 125 | 1/15 | 11 | 0 |
| 2 | 25.1 | 9/9 | 9/9 | 6 | 10/4 | 25 | 10/19 | 14 | 49 |
| | | | | 7 | 10/29 | 50 | 11/19 | 20 | 60 |
| | | | | 8 | 11/25 | 75 | 12/10 | 15 | 52 |
| | | | | 9 | 12/17 | 100 | 1/5 | 19 | 46 |
| | | | | 10 | 1/11 | 125 | 1/20 | 9 | 54 |
| 3 | 23.4 | 9/19 | 9/19 | 11 | 10/14 | 25 | 10/25 | 11 | 100 |
| | | | | 12 | 11/8 | 50 | 11/27 | 19 | 98 |
| | | | | 13 | 12/3 | 75 | 12/19 | 16 | 100 |
| | | | | 14 | 12/28 | 100 | 1/10 | 13 | 96 |
| | | | | 15 | 1/22 | 125 | 2/5 | 14 | 97 |

TABLE VI. THE RELATION OF TIME OF PICKING AND TIME IN COLD STORAGE TO THE DEVELOPMENT OF CORE BREAK-DOWN IN BOSC PEARS

(Delayed cold storage) (Willamette Valley Bosc)

| Lot number | Pressure test (pared specimens) | Date of picking | Date of cold storage | Box number | Date of removal from cold storage | Number of days in cold storage | Date of prime condition | Number of days to attain prime condition out of cold storage | Amount of core break-down |
|---|---|---|---|---|---|---|---|---|---|
| | *lbs.* | | | | | | | | % |
| 1 | 27.7 | 9/2 | 9/12 | 1 | 10/6 | 25 | 10/16 | 10 | 0 |
| | | | | 2 | 11/1 | 50 | 11/24 | 24 | 0 |
| | | | | 3 | 11/26 | 75 | 12/9 | 13 | 0 |
| | | | | 4 | 12/22 | 100 | 1/5 | 14 | 0 |
| | | | | 5 | 1/15 | 125 | 1/25 | 10 | 0 |
| 2 | 25.1 | 9/9 | 9/19 | 6 | 10/15 | 25 | 10/25 | 10 | 32 |
| | | | | 7 | 11/8 | 50 | 11/27 | 19 | 46 |
| | | | | 8 | 12/3 | 75 | 12/15 | 12 | 55 |
| | | | | 9 | 12/28 | 100 | 1/5 | 8 | 51 |
| | | | | 10 | 1/22 | 125 | 2/2 | 11 | 48 |
| 3 | 23.4 | 9/19 | 9/29 | 11 | 10/24 | 25 | 11/4 | 11 | 100 |
| | | | | 12 | 11/19 | 50 | 12/3 | 14 | 96 |
| | | | | 13 | 12/13 | 75 | 12/22 | 9 | 100 |
| | | | | 14 | 1/7 | 100 | 1/17 | 10 | 100 |
| | | | | 15 | 2/2 | 125 | 2/8 | 6 | 100 |

The length of the proper picking season for any given lot of Bartlett grown in the Willamette Valley can be set conservatively at 15 to 18 days. For the Rogue River Valley and for some of the districts east of the Cascade Mountains the season can possibly be extended a little beyond these figures. The range of picking dates for Anjou from the Willamette Valley probably varies between 12 to 16 days, that of Winter Nelis between 14 and 18 days, that of Comice and Bosc between 6 and 8 days. As in the case of Bartlett, the picking season for these winter sorts when grown east of the mountains or in the southern part of the state can perhaps be extended a few days. Comice and Bosc evidently have a comparatively short harvesting period. This, in all probability, accounts for the common occurrence of core break-down in these varieties.

**Core break-down is not influenced by storage.** The amount of disease that ultimately develops does not seem to be influenced by either the kind or manner of storage. In the present experiments the rate of development was practically the same whether the fruit was kept in cold or in common storage, whether the storage period was long or short, or whether storage was immediate or delayed.

**Calendar dates are not reliable indicators of maturity.** That calendar dates alone are not reliable indicators of maturity in pears is shown by the results of these investigations. As indicated by ripening dates, for example, the season of 1924 was generally from 10 to 12 days earlier than the season of 1923. Many growers, however, were not fully aware of this fact and records show that in many cases the pear crop was harvested on approximately the same dates during both seasons. This may well account for the fact that core break-down was much more common in 1924 than in 1923. Again, the proper time of picking may vary from year to year because of the amount and nature of the crop. Experiments have shown that the proper picking season during heavy crop years may be several days in advance of that in light crop years.[8] The vigor of the trees also may influence maturity in some cases. Maturity, too, may vary considerably in the same locality because of the slight differences in the situation of the orchard. It is a well-known fact, for example, that the pears from the river bottoms of the Willamette Valley ripen several days ahead of those from the hill districts.

**Pressure test is effective in control of core break-down.** The pressure tester already described in the literature of this Station again proved to be a fairly reliable indicator of maturity in pears and at this time appears to be the most effective weapon in the control of core break-down.[7, 8] In fact, core break-down has practically ceased to be a factor where the pressure tester has been intelligently applied.

Experimental data as well as practical experience show that in the case of Bartlett no core break-down has been encountered when harvesting has been done at pressures ranging from 35 to 25 pounds. This apparently holds true for the principal pear districts of the state. Anjou has remained free from core break-down and has yielded fruit of good quality when picked at pressures varying between 24 and 19 pounds. Comice has given fairly satisfactory results at pressures between 20 and 18 pounds, and Winter Nelis has been successfully harvested at pressures between 28 and 24 pounds on clear skinned specimens. Bosc in the Rogue River Valley can generally be picked within a pressure range of

24 to 20 pounds. Willamette Valley Bosc, on the other hand, are generally firmer in texture and must be picked at pressures that are considerably higher. Again, Bosc from this region are usually covered with russet of varying intensity, and experience has shown that it is best to pare the specimens prior to making the pressure readings. Taking these factors into account, the range of suitable picking pressures for Willamette Valley Bosc seems to be between 30 and 27 pounds. Fig. 2 shows in graphic form the recommended pressures for the different varieties.

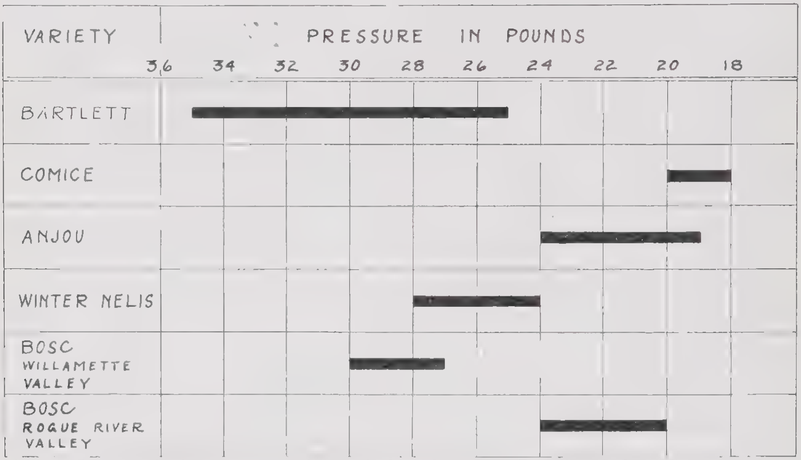

Fig. 2. Proper picking pressures for varieties of pears. Core break-down has practically ceased to be a factor where the pressure tester has been intelligently applied.

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Station Bulletin 217 August, 1925

# Oregon Agricultural College

# Experiment Station

# Perennial Canker of Apple Trees

*(A preliminary report)*

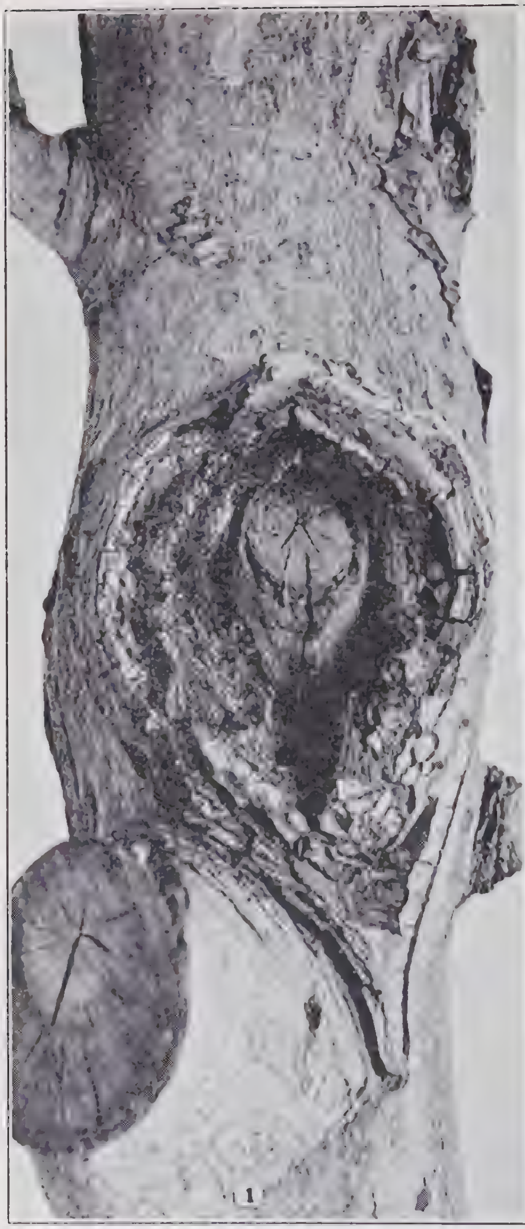
By

S. M. ZELLER and LEROY CHILDS

1885

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.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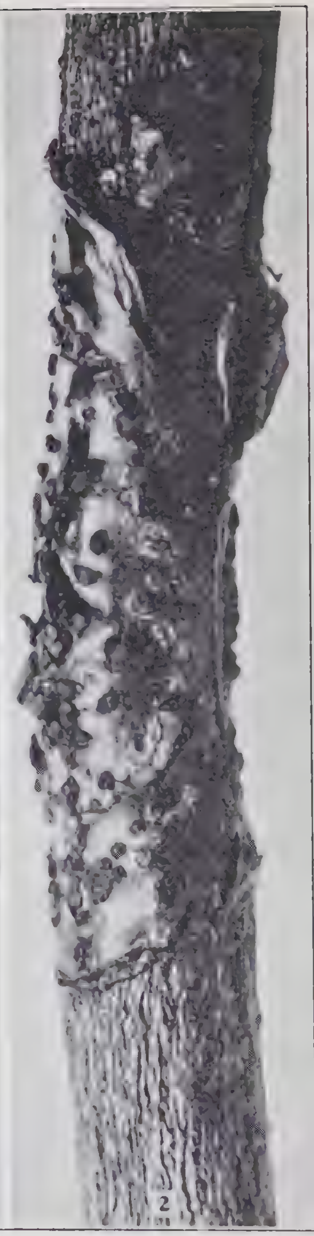
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Fig. 1. A five-year-old perennial canker which started from a pruning cut on a scaffold branch. Notice the woolly aphis where a scale of dead bark has been removed.

Fig. 2. Perennial canker on tiny apple twig showing circular, waxy fruiting bodies breaking through the epidermis. (Magnified 3½ diameters).

# SUMMARY

In this bulletin is described the perennial canker of apple trees, a disease which, in some of its stages, is very difficult to distinguish from the apple-tree anthracnose caused by *Neofabraea malicorticis*. The known distribution of the disease ranges from the Okanogan Valley, British Columbia, to the Willamette Valley, Oregon. It has also been reported from the Spokane and Wenatchee valleys in Washington, from certain stations along both sides of the Columbia River, and especially the Hood River Valley, where the disease is well distributed in the upper and lower valleys. The disease differs from apple-tree anthracnose at least in four distinct ways: (1) its perennial character, (2) it is more distinctly a wound parasite than anthracnose, (3) the shape of the conidia, and (4) its reactions on media in culture. Since this disease appears to be undescribed the name **Gloeosporium perennans** Zeller and Childs sp. nov. is proposed and **"perennial canker"** is given as a common or horticultural name.

No preventive measures of control are yet positively known for this disease. However, the liberal use of bordeaux mixture, particularly the spring application of bordeaux-oil, appears to be of some assistance in checking the advance of the disease. In districts where the disease is present pruning should be reduced to a minimum until control measures are better understood. Cuts on the main scaffold branches of the trees should be avoided as much as possible. Eradication measures involve cutting out the diseased tissues and painting over all cleaned-out wounds, whether cleaned-canker wounds, pruning cuts, or other injuries, with an antiseptic wound dressing, preferably bordeaux paste made up in raw linseed-oil.

# Perennial Canker of Apple Trees

*(A preliminary report)*

By

S. M. Zeller and Leroy Childs

## INTRODUCTION

For a number of years two distinct apple-tree anthracnoses have been prevalent in the Northwest, but since their distinguishing characteristics had not been recognized the two forms have been grouped under the Northwest apple-tree anthracnose caused by *Neofabraea malicorticis.* For some time considerable difficulty has been encountered in the control of one of these anthracnoses in certain orchards of the Hood River Valley. This led to a more definite investigation of the fungus concerned. As a consequence we have just found this spring (1925) that there are two distinct forms and now are able to distinguish between them, as previously reported.*

The well known apple-tree anthracnose infects during the fall and winter months, producing a canker wherever a spore alights upon the bark. It is a virulent parasite, which does not usually enter through wounds. The newly found anthracnose, which we are calling *Perennial Canker,* enters through wounds and produces a canker around these wounds. This canker grows from year to year, producing new growth around the older canker, so that there is a definite annual canker enlargement. On the other hand, the well known anthracnose grows for one year in the healthy bark, the wound callusing over and the disease not extending itself into the surrounding healthy tissues during succeeding years, except where new infections take place near the margins of old cankers. Those who have had experience in controlling anthracnose believe that the two conditions, biennial and perennial canker, have been with us for a considerable time preceding the records we now have.

## DISTRIBUTION AND OCCURRENCE

The geographical distribution of the perennial canker in the Pacific Northwest so far as we have learned at present is pretty well over the apple growing districts of Oregon, Washington, and British Columbia. In Oregon this canker has been found to occur in many parts of the Willamette Valley, it having been received from Brownsville, Corvallis, Monroe, and Salem. In the Hood River Valley it has been found to occur throughout the upper and lower valleys. In Eastern Oregon, specimens have been received from the Milton-Freewater, The Dalles, and Mosier districts. The canker also occurs in the Wenatchee, White Salmon, and the Spokane valleys as well as Clark and Skamania counties of the state of Washington, and in the Okanogan district of British Columbia. In all of these districts the canker is becoming more prevalent and a rather serious disease in those orchards affected.

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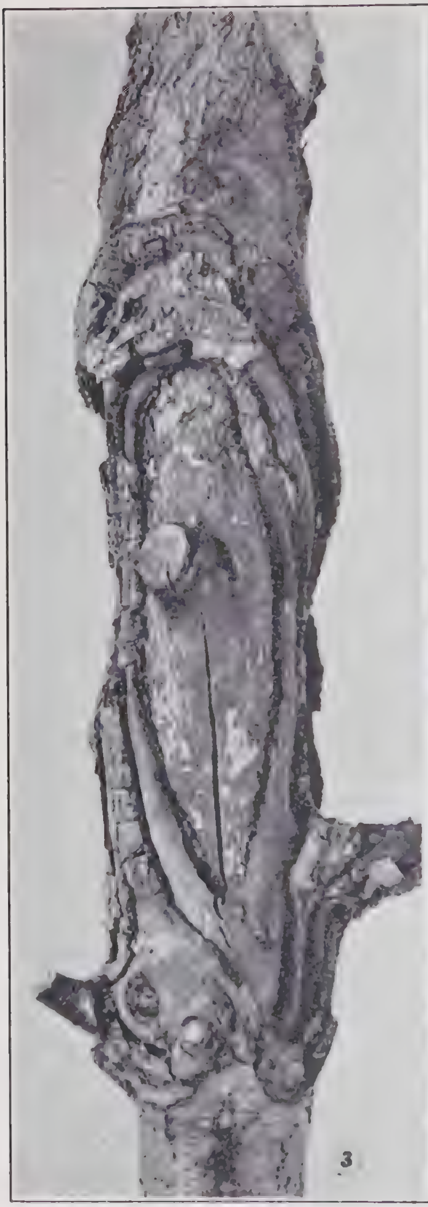
*Zeller, S. M. and Childs, Leroy. Another apple-tree anthracnose in the Northwest and a comparison with the well known apple-tree anthracnose. Paper presented before American Phytopathological Society, Pacific Division. June 23, 1925. (Abstract to appear in Phytopathology.)



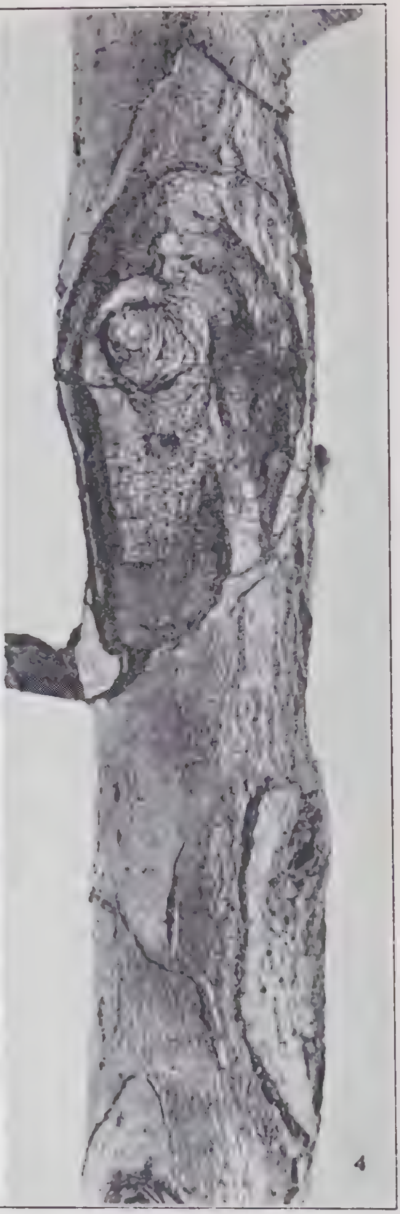


Fig. 3. A five-year-old perennial canker. Notice the concentric annual growth rings.
Fig. 4. Showing three-year-old and two-year-old perennial cankers with diseased bark still adhering.

The occurrence of the canker on different hosts has not been surveyed adequately, but some observations have been made concerning the varieties susceptible, as far as this can be determined by prevalence of the canker. In the Hood River Valley the predominant susceptible variety is the Newtown Pippin, followed in order of susceptibility by the Ortley, Gravenstein, Jonathan, and Winter Banana. The Delicious, Arkansas Black, Black Twig, and the Winesap, appear to be quite resistant to the disease in the Hood River district. The Baldwin also appears to belong to this group as this variety has been observed situated among severely cankered varieties without developing infection. In the Willamette Valley the canker has been found on Newtown and Delicious apples, and the Bartlett pear. On the last mentioned variety the cankers were limited to last year's wood, such as water sprouts or suckers from the base of the trunk. Mr. D. F. Fisher, Plant Pathologist, of the United States Department of Agriculture, stationed at Wenatchee, Washington, reports that in the Wenatchee Valley, Spitzenberg trees are the ones affected by this canker, while neighboring Winesap trees are free from canker.

## TIME OF APPEARANCE

The information we have at this time concerning the time of appearance of the canker is rather meager. We do know, however, that conidia are liberated in the spring. This spring (1925) the acervuli opened early in May and continued to liberate spores until in the month of June. Last year an apple grower in the Hood River Valley stripped off the water sprouts along the larger scaffold branches of his trees during the latter part of May and the first part of June. This year nearly every wound produced in this way is the center of a perennial canker. Presumably, then, infections take place during the spring, but the time of canker enlargement is still in doubt; although, since definite calluses fissure the bark at the margins of cankers during the spring months we anticipate that canker enlargement must take place during the fall and winter or at least very early spring as in the case of apple-tree anthracnose. It would appear, then, that infection taking place in the spring is followed by a hibernation of the mycelium during at least a portion of the summer and then a development of the fungus after the rains begin, with the maturity of acervuli coming in the spring. With addition of moisture the acervuli are easily rejuvenated and caused to sporulate in the laboratory. For this reason it is assumed that with the first rains in the fall months sporulation may be resumed for a time and possible infection may take place then.

## RELATION TO BARK AND TWIG LESIONS

The occurrence of cankers on a tree bears a definite relation to various types of wounds. Pruning wounds invaded by the fungus appear to be the location of the greatest number of cankers, particularly those located on the scaffold branches of the infected tree. (Figs. 1, 3, and 6.) These wounds appear to be especially liable to infection following extremely low temperatures and infestation by woolly aphis. Other common locations of infection are broken twigs and spurs (Figs. 9 to 12), pickers' scars and injuries produced by propping up the branches. All injuries to the bark apparently become possible centers of infection. Where woolly aphids produce lesions along water sprouts these lesions are sure to be infected in badly cankered

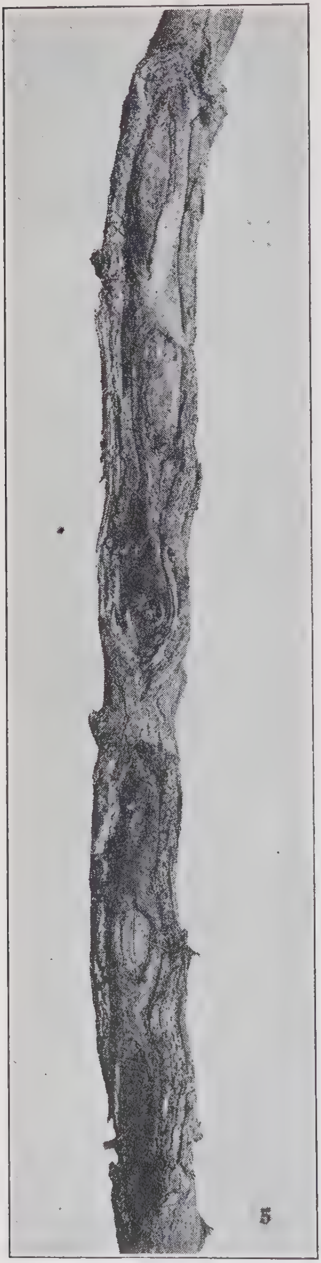


Fig. 5. A badly cankered Newtown branch.

orchards (Figs. 7 and 8). Many water sprouts found on cankered trees are infected throughout their length because of the previous injury by aphids. A canker often forms on the branch at the base of a killed water sprout.

Judging from the width of the growth areas of canker following the extremely low temperatures of December, 1919, and the winter of 1924-25, it is rather apparent that this canker is worse during the years following extreme winters. As in the case of bitter-rot,* this canker infects and lives over in other types of cankers, such as the Northwest apple-tree anthracnose (Fig. 5) and European canker. Since the apple-tree-anthracnose canker may be bordered with a ring of diseased bark-tissue invaded by the perennial canker fungus, it has been thought by some that during the springs following cold winters the apple-tree anthracnose continues to grow in the bark surrounding old anthracnose cankers. Thus there has been in the past a confusion of the two diseases. This may be the unusual perennial condition to which Jackson has referred and also may be the grounds for Mr. Lownsdale's contentions cited by Jackson.** The fact that the perennial canker infects through wounds is one of the predominant distinguishing characteristics between this canker and the apple-tree anthracnose. The accompanying illustrations show some of the typical cankers surrounding wounds of various causes (Figs. 1 to 12).

## GENERAL DESCRIPTION OF THE CANKER

Cankers are found on branches of various sizes, from last year's wood up to branches of five to six inches in diameter in vigorously growing trees. Cankers are rarely found below the main crotches in the scaffold branches, except in such instances when trunks have suffered winter injury. In such cases the disease spreads rapidly making winter injury a real menace to the life of the whole tree. The very earliest stages of the canker appear considerably lighter than in the case of apple-tree anthracnose. The color of the canker depends considerably on the age of the bark and seems to vary with climatic conditions in different localities. Cankers on very young water sprouts or on one-year-old wood have a light tannish-brown appearance, with a glassy surface. This brownish appearance may be alternated with concentric rings of a purplish-brown color. In cankers working in older bark the color is of a reddish-brown, or purplish tint, with a tendency to concentric rings of lighter coloration at the time when the acervuli begin to form. The acervuli appear more or less in concentric order as illustrated in Figs. 2 and 10 to 12. In the spring when the healthy wood surrounding a canker begins to grow, a fissure is produced rather definitely limiting the edge of the canker. This gives to the canker a sunken appearance which is augmented by the drying out of the affected portions of the bark. This appearance is plainly shown in Figures 7 to 12. In those portions of a canker where the acervuli are fully developed it is very difficult to distinguish the perennial canker from the same stage of the apple-tree anthracnose, caused by *Neofabraea malicorticis.* As the canker matures, the dead bark may appear cracked and fissured, and in some instances breaks away from the wood. Usually, however, as the bark dries out it adheres very firmly to the underlying wood, and may become smooth and glassy, rather than cracked into rectangular pieces. Around the dead area the healthy bark begins to heal over, forming a callus layer at the time when the fungus becomes inactive. This callus at the margins of the dead bark forces its way inward, usually lifting the dead bark, at least around the borders of the canker. This gives to the canker more of a sunken appearance than the mere drying of the diseased bark will produce. During the next season of mycelial growth the fungus makes inroads on the surrounding healthy callus formed the previous year. Sometimes this additional growth reaches a width of ¾ of an inch. Usually, however, it is less than this in a lateral direction. As would be expected, however, the growth in a direction longitudinal with the branch is more rapid, causing an elliptically-shaped canker. Year after year, then, these new calluses are formed concentrically, as is so commonly described for the open type of European canker. Sometimes the old bark adheres for several years (Fig. 4), but it usually drops away after the second year (Fig. 3). In cross-sections the wood of the branch immediately below the canker is discolored for a considerable distance toward the pith. The discoloration is brown and resembles the brown in many kinds of trees below similar wounds. The perennial character of the canker is strikingly brought out in certain cross-sections which show discoloration of the wood below the various rings, or calluses formed during succeeding years of the mycelial growth. This does not extend far into the wood during the last two or three years of the progress of the canker-fungus, but we have not ascertained how far the mycelium penetrates the wood below healthy bark nor whether this is a factor in canker enlargement.

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*Roberts, J. W. Sources of the early infections of apple bitter-rot. Jour. Agr. Res. 4:59—64. 1915.

**Jackson, H. S. Apple Tree Anthracnose. Ore. Exp. Sta. Crop Pest and Hort. Rept. 1911—1912:178—197. 1913 (See page 193).

The canker continues to increase in size for several years. Cankers showing six and seven concentric calluses have been found. These are illustrated in Figs. 3 and 5. This perennial character of the canker is one of extreme importance to be considered in connection with the control measures necessary to eradicate the canker from infected orchards.

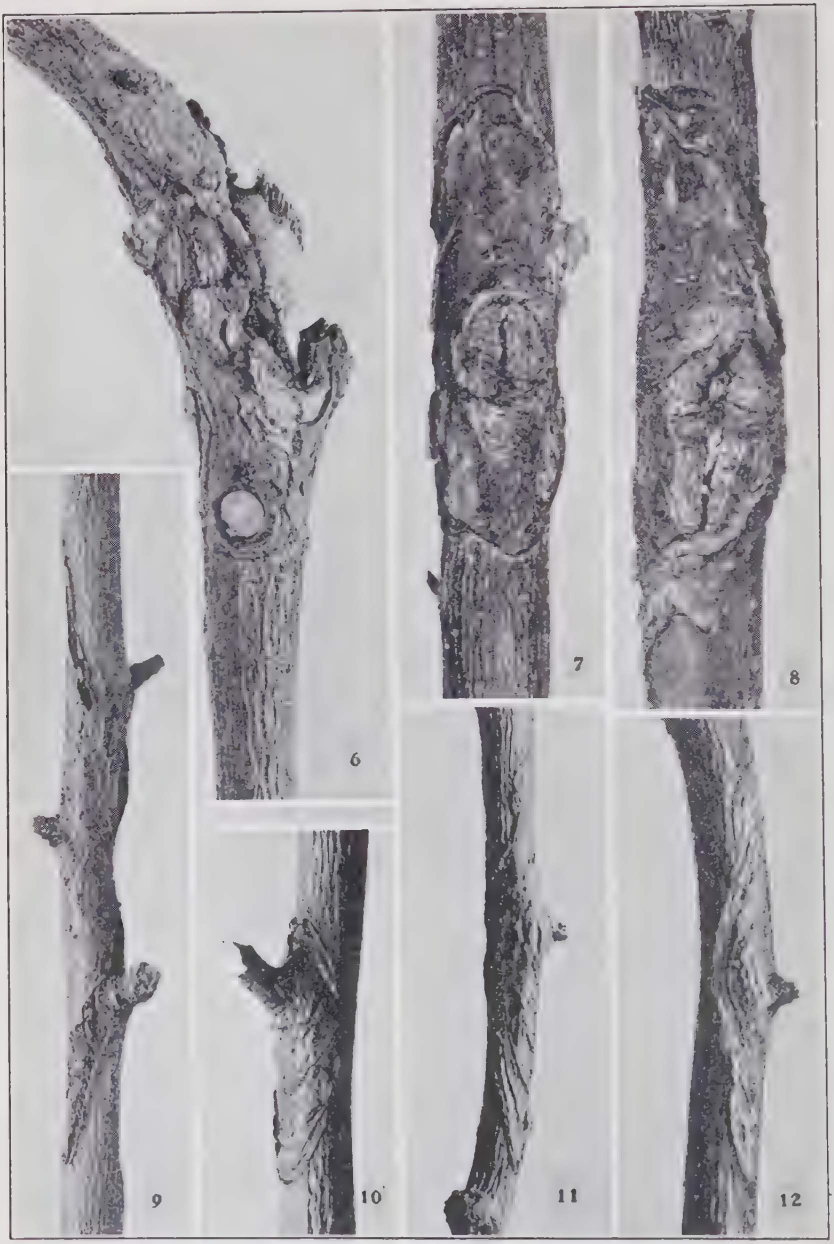


Fig. 6. Perennial canker starting at a pruning cut.
Figs. 7 and 8. Perennial cankers starting in lesions caused by woolly aphis.
Figs. 9 to 12. Perennial cankers illustrating infection through injured twigs.

## DESCRIPTION OF THE FRUIT ROT

The fruit rot produced by this disease of apple trees has not proved of definite economic importance in Oregon so far as is known. Usually the fruit has been covered with the fall spray for the control of apple-tree anthracnose before picking and this may reduce to a minimum the fruit rot in storage. However, it will never be known how much of the apple-tree-anthracnose fruit rot which has been reported in the past is due to this fungus causing the perennial apple-tree canker. It perhaps should be stated at this time that for several years apples shipped to eastern markets from the Wenatchee Valley, in the state of Washington, were received with considerable rot, which has been reported as anthracnose, or, perhaps more recently, as "a false anthracnose." No apple-tree anthracnose caused by *Neofabraea malicorticis* has ever been reported from the Wenatchee Valley. Thus, since the anthracnose canker was not known in the Valley, it was believed that the reports of anthracnose rot from eastern markets could not be correct. After consideration it was found that this rot did not appear exactly the same as the rot produced by the Northwestern anthracnose, and so for a number of years pathologists and fruit inspectors have considered this as another type of anthracnose, although the exact origin of the difficulty was not discovered until this year, when D. F. Fisher found perennial canker upon Spitzenberg trees in the Wenatchee Valley.

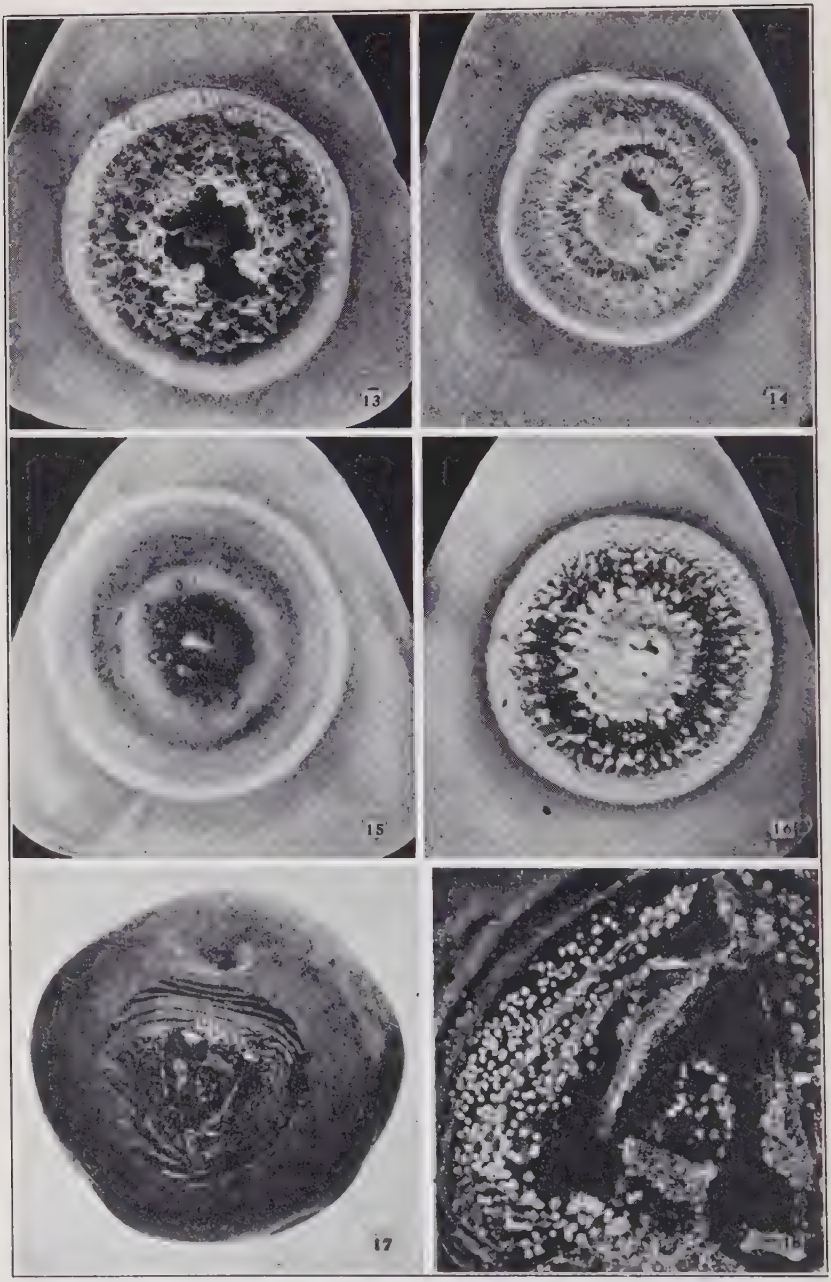
Apples inoculated with the perennial-canker organism produce a brown, soft rot. The zonation so characteristic of anthracnose rot is not apparent, although this zonation is not a constant character of anthracnose rot as a result of inoculation in the laboratory. The illustration (Fig. 17) shows a Red Astrachan apple inoculated with the perennial canker organism after twenty-eight-days incubation. The acervuli, or fruiting bodies were well developed and sporulating readily as shown in Fig. 18. The spores bore the characteristics of those from the cankers. They bear a striking contrast to the characteristically curved spores of *Neofabraea malicorticis* from apple fruit. Compared with the bitter-rot, another anthracnose of eastern and southern states, the rot produced by the perennial canker organism is much less rapid in its development, sporulates less readily on fruit lesions, has creamy white spores (in mass) while those of bitter-rot are pink, and the shape of the spores is distinct.

## DESCRIPTION OF THE FUNGUS IN CULTURE

The perennial canker organism has been isolated both from apple and pear cankers by means of sterile tissue transplanted to agar slants and by the dilution plate method of isolating spore cultures. The latter method has been used the more frequently. Pure cultures have been isolated from cankers from the various localities reported below under "Specimens Examined."

**Spore germination.** Spore germination tests were made in hanging drops of tap and distilled water and potato-glucose agar, corn agar, and oat agar.

There were no apparent differences between the germ tubes and sporulation produced in distilled and tap water for the period of time the hanging drops were observed. Figure 19 illustrates various stages of conidiospore germination and production of secondary spores in tap



Figs. 13, Perennial canker organism growing on corn-dextrose agar, showing abundant mycelial growth; 14, Apple-tree anthracnose organism growing on corn dextrose agar; 15, Perennial canker organism growing on corn agar. Notice *very narrow* "halo" of starch-free agar at margin; 16, Apple-tree anthracnose organism growing on corn agar. Notice *wide* "halo" of starch-free agar at margin; 17, Red Astrachan apple inoculated with perennial canker organism, after twenty-eight-days incubation. Notice rot with fungus fruiting; 18, Portion of rot shown in Fig. 17, enlarged 3½ diameters to show fruiting bodies of fungus.

water. Germ tubes begin to appear in three to four hours and simultaneously the spores become one-septate where one germ tube is thrown out, but become one- or two-septate where two or more germ tubes are produced. The conidia which are usually indistinctly, if at all, granular usually become netted vacuolate and more distinctly granular when germination begins. The germ tubes are produced near the end of the spore, usually slightly to one side, or near a septum. They become septate, producing secondary spores just below the septa in a more or less alternate or spiral fashion. These secondary spores are produced in succession from the same point, but in such a dilute medium as tap water, the spores become disconnected and float away. Secondary spores produced in water are 3—6 x 1—1.5 microns, ovoid to ellipsoid, while those produced in agar are 5—10 x 1.5—2 microns, ellipsoid and although the latter are produced successively from the same point they are crowded aside and held in groups in the hard medium, as illustrated in Fig. 20. The germination and septation in agar is similar to that described above for water cultures. The production of secondary spores in agar cultures is very similar in the three fungi, which cause apple-tree anthracnose, bitter-rot, and perennial canker.

**Culture media.** The organisms concerned in the three diseases just mentioned have been grown in pure cultures on the following media: Czapek's solution, Richard's E solution, apple and sweet clover stems, potato-glucose agar, corn-meal agar with and without dextrose, and oatmeal agar with and without dextrose. It was soon learned that the perennial canker fungus was more closely like anthracnose in culture while the bitter-rot organism is easily distinguishable. A thorough discussion of the physiology of the perennial canker organism as studied in culture will be reserved for a future publication, but some of the points of difference between this organism and apple-tree anthracnose should be pointed out here. These two fungi react to culture media quite similarly in many respects and are quite sensitive to changes in nutrition. For this reason the growth characters of either organism may vary on two different lots of the same medium made up according to the same formula, for it is not usual to get the same exact proportions in two instances. However, when several cultures of the two organisms on the same lot of a medium are observed over a period of twenty days or more, some few striking differences are apparent. Neither organism grows well in Czapek's or Richard's E solutions. The hard agar media are more conducive to growth and sporulation. The reactions of the two organisms on oat and corn agar are very similar and some of the growth reactions on the latter will be described. The growth reactions described immediately below are illustrated in Figs. 13 to 16. The anthracnose organism grows well whether dextrose is given or not. When corn-meal without dextrose supplies the nutrient the diastatic activity, as shown by the clear "halo" of starch-free agar immediately surrounding the mycelium (Fig. 16), is very positive. With this liberation of assimilable carbohydrate the fungus vegetates abundantly as illustrated by the prolific mycelial growth. When additional carbohydrate in the form of dextrose was given, vegetative growth was abundant without noticeable diastatic activity (Fig. 14). On the other hand, the vegetative growth and diastatic activity of the perennial canker organism is less apparent when dextrose is not given than is true in the case of anthracnose (Fig. 15). When dextrose is given, however, the perennial canker organism vegetates as abundantly as does anthracnose (Fig. 13). The writers are now conducting further experiments with these two organisms to learn whether anthracnose also possesses a greater power than the perennial canker organism to hydrolyze other higher carbohydrates to assimilable forms and to reduce other unavailable foods to available forms. Surely in nature the anthracnose organism is a much more virulent parasite than the perennial canker organism, which is perhaps due to the greater power of the former to penetrate the bark because of certain of these enzymic properties.

## THE CLASSIFICATION OF THE CAUSAL ORGANISM

The fungus causing perennial canker is typical of those species grouped under the form-genera, *Gloeosporium* and *Myxosporium.* Since the organism concerned in this bulletin causes both the canker of the bark and the rot of the fruit of apple, sporulating upon both, and since no perfect spore stage has been discovered, we have chosen to include it in the form-genus, *Gloeosporium,* rather than *Myxosporium,* to which are referred only those species inhabiting bark. Since the species is evidently undescribed we propose the name, *Gloeosporium perennans* sp. nov., of which a formal description with notes concerning distribution and specimens examined are included in the accompanying footnote.[1]

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[1] **Gloeosporium perennans** Zeller and Childs, sp. nov.

*Acervuli* originating subepidermally or deeper, erumpent, circular, irregular when coalescing, minute, 400—700 microns in diameter, (larger when coalescing), thickness from substratum variable, 250—600 microns, drying "tawny" to "mummy brown" (Ridgway), lighter when moist or freshly erumpent, at first composed of an erect cylinder of sterile, hyaline hyphae, which is later surrounded by conidiophores and finally submerged by conidiophores; *conidiophores* divergent, suberect, branched, septate, hyaline; *conidia* hyaline, irregular in shape and size, mostly ellipsoid, usually larger at one end, seldom slightly curved, 12—20 x 4—6 microns; producing secondary conidia in culture; *secondary conidia* hyaline, variable in size, 3—10 x 1—2 microns, ovoid to ellipsoid, sometimes curved.

Causing a perennial canker of the bark of *Pyrus malus,* to a less extent on *P. communis,* and fruit rot of the former.

Known distribution: Oregon, Washington, and British Columbia.

Specimens examined: British Columbia: Okanogan Center, *H. H. Evans* (in O. A. C. Herb., 4835).

Washington: Chelan county, Wenatchee, *D. F. Fisher* (in O. A. C. Herb., 4838, and Zeller Herb., 6839); Skamania county, Husum, *W. B. Rine* (in O. A. C. Herb., 4836, and in Zeller Herb., 6845); Spokane county, *F. C. Neilson* (in O. A. C. Herb., 4837, and Zeller Herb., 6849), *D. F. Fisher* (in Zeller Herb., 6850).

Oregon: Benton county, Corvallis, *C. E. Owens* (in Zeller Herb. 6833), *S. M. Zeller* (in O. A. C. Herb., 4840, and in Zeller Herb., 6835); Monroe, *S. M. Zeller* (in Zeller Herb., 6846); Hood River county, Hood River, *Leroy Childs* (in O. A. C. Herb., 4841, and Zeller Herb., 6847), *F. M. Green* and *S. M. Zeller* (in O. A. C. Herb., 4839), *Harry E. White* (in O. A. C. Herb., 4843), *S. M. Zeller* and *Leroy Childs* (in O. A. C. Herb., 4844); Parkdale, *Leroy Childs,* type (in O. A. C. Herb., 4845); Linn county, Brownsville, *Oren Stratton* (in O. A. C. Herb., 4846); Marion county, Salem, *H. P. Barss* (in O. A. C. Herb., 4847); Umatilla county, Milton, *A. R. Kirk* (in O. A. C. Herb., 4848).

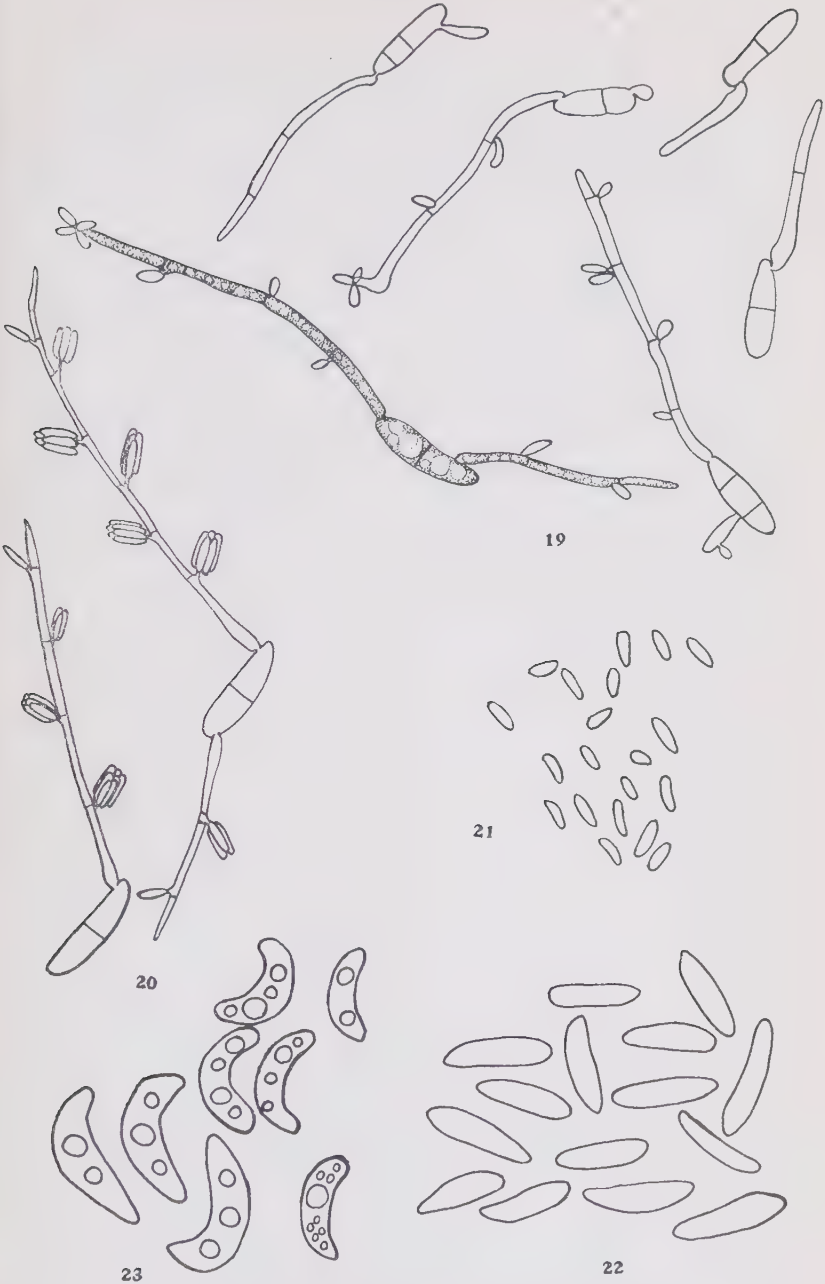

Fig. 19. Germinating conidia of the perennial canker organism, showing septation and microconidia produced in water. X 770.

Fig. 20. Same as Fig. 19 but produced in corn agar. X 770.

Fig. 21. Secondary spores of the perennial canker organism produced in culture. X 770.

Fig. 22. Conidia of the perennial canker organism produced on apple canker. X 770.

Fig. 23. Conidia of apple-tree anthracnose produced on canker. X 770.

## HOW DO PERENNIAL CANKER AND APPLE-TREE ANTHRACNOSE DIFFER?

Several differences between these two cankers have been pointed out in preceding paragraphs but it perhaps would be well to reiterate them here in rather concise statements. In their early stages the two cankers look very much alike. The following are the distinctions which may be made:

1. The perennial canker is a wound parasite infecting through wounds of various causes such as pruning cuts, or any other mechanical injury to the bark, lesions caused by other cankers such as anthracnose and European canker, winter injured bark and the lesions produced by such insects as woolly aphis (Figs. 1 to 12). On the other hand, anthracnose is a very much more virulent parasite, usually having its incipient infections through uninjured bark.

2. The perennial canker develops year after year by the spread of the fungus in the healthy tissues surrounding the canker of the previous season (Figs. 3 and 5) while anthracnose does not spread farther than the limits of the first year's growth, although the fungus lives in the dead tissues of a canker through the second year when the spores of the perfect stage are formed and discharged.

3. The conidiospores in the two organisms are distinct, those of anthracnose having a characteristic curve or hook (Fig. 23), while those of the perennial canker organism are generally ellipsoid although variable in shape and size, as given in the description (Fig. 22).

4. The two organisms react to certain culture media in distinct ways. The chief distinction in this respect, so far discovered by us, is the more active diastatic power of the anthracnose organism (Figs. 13 to 16).

## ECONOMIC IMPORTANCE AND CONTROL MEASURES

On account of the nature of the injury produced by this disease the losses due to it are difficult to estimate. In many large orchards of the Hood River Valley, however, the disease has done extremely serious damage. Branches from the small one-year-old twigs up to scaffold branches four to six inches in diameter may be girdled because of the frequency of coalescing cankers. In some of the orchards where infection is at its worst more than 300 cankers were counted on a tree not more than 15 years old. The cankers vary in size according to their age and the size of the branch affected. On healthy branches cankers may be found up to 10 inches in length but in case of infection following winter injury affected bark may extend for considerable lengths. Because of the perennial nature of the disease the cankers must be thoroughly cleaned out by cutting out the individual cankers or they will continue to become an increasing source of infection. Some growers in districts where perennial canker has become wide-spread declare that it is useless to attempt to clean up an orchard where cankers are so frequent on trees. Perhaps this is an extreme attitude, nevertheless the wholesale removal of cankers from large trees where scores of cankers occur is an expensive and laborious operation, providing the surgical methods are done adequately and carefully enough to effect sure eradication. And it would seem that the perennial nature of the disease would make this process of eradication the only feasible one.

There appears to be the possibility of a definite relationship between the woolly aphids to infection and growth of the canker. Fully 90 percent of the cankers examined have been heavily infested by this insect. Old, sound, pruning wounds on infected trees are, so far as observed, always free of the aphids or galls caused by them. Water sprouts infested with aphids usually die as a result of the presence of perennial canker while no such infection or resulting effect takes place on aphid-free sprouts. Further study may show that woolly aphids have nothing to do with the advance of the disease, but as a preliminary precautionary measure, control of the aphids is suggested. Exposed woolly aphids can be controlled by the application of Black Leaf 40, 1 part to 1,000 parts of water, plus calcium caseinate spreader, 2 parts to 100 parts of water. Preferably this should be applied as soon as the insects begin to appear on the shoots. This period in their development is usually reached after the middle of July.

The liberal use of bordeaux mixture may assist somewhat in checking the advance of the disease because those orchards which have been well sprayed, particularly with the bordeaux-oil combination, are in better shape than those receiving no spray. However, satisfactory control of perennial canker has not been obtained in tests being carried on at Hood River for the control of anthracnose *(Neofabraea malicorticis)*. These tests have involved spring, summer and fall application of bordeaux mixture and have indicated that measures other than the application of this fungicide will be necessary if control is to be obtained. For the present, at least until the control of the disease is better understood, one thorough application of bordeaux mixture is advised, preferably the spring bordeaux-oil combination. The 6-6-50 bordeaux formula, to which should be added a good 6 to 8 percent oil spray, is suggested as an early pre-pink application. This also controls the leaf-roller. Surgery should also be resorted to, particularly in the case of large cankers or cankers located on the larger branches. Branches with many cankers (Fig. 5) and those practically girdled should be removed as a whole. In cases where individual cankers are to be removed, the discolored, affected bark should be cut well back into the healthy tissue. Probably this can be done best during early summer as cutting at this time will permit the development of a maximum callus. A good, straight-bladed knife, such as that employed for budding, has been found suitable for cutting out cankers. This should be kept sharp, as a clean, perpendicular cut into healthy bark is desirable. After a canker is well cleaned, the wood should be coated by an antiseptic. For such purposes we have been having good success with a tree paint made up in the following manner. Into any desirable amount of a bordeaux powder, such as the Sherwin-Williams Fungi Bordo, slowly stir small amounts of raw linseed-oil until a rather thick, *smooth* paint is formed. This may be applied with a paint brush. All pruning cuts or other wounds of any size should be coated for these are all sources of infection.

The Oregon Experiment Station is now working to ascertain the most practical methods of eradication and prevention, and any progress will be announced as soon as possible.

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Station Bulletin 218 August, 1925

# Oregon Agricultural College

# Experiment Station

Umatilla Branch Experiment Station

# Fattening Lambs for the Late Winter Market

By

H. K. DEAN

and

E. L. POTTER

Lambs marketing alfalfa at the Umatilla Branch Experiment Station.

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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## SUMMARY

From October until April the average increase in the Portland lamb market is 52 cents per hundred pounds per month.

Average range lambs will fatten in 60 to 90 days with one pound of grain per day and all the alfalfa they wish.

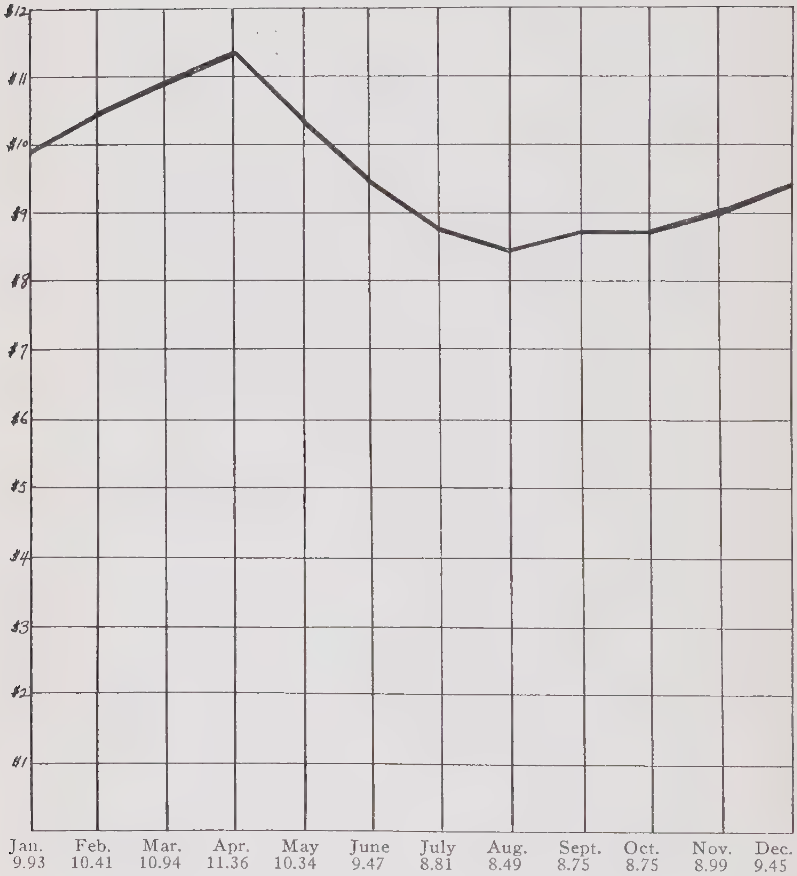
Lambs to be marketed in March and April should be fed alfalfa alone until 60 to 90 days before the time they are to be marketed, and then given grain at the rate of one pound per head per day.

Small lambs on hay alone will eat about 80 pounds a month.

Lambs on hay alone will make but very little gain, but the increase in market during the winter months will usually pay a fair price for the hay.

Feeding lambs hay alone for a while before beginning the grain feeding makes it possible to market twice as much alfalfa on a given investment in lambs and grain.

AVERAGE MONTHLY TOP PRICES OF LAMBS
AT NORTHt PORTLAND, 1910-1924



# Fattening Lambs for the Late Winter Market

By

H. K. Dean

and

E. L. Potter

The object of the tests described in this Bulletin was to study methods of fattening lambs for the March and April market, partly to take advantage of the better prices which normally prevail during the late winter months, and partly to market a larger quantity of alfalfa.

### Excessive Investment Required for Short Feed

The usual method of fattening range lambs is to feed about 75 days on a daily ration consisting of one pound of grain to three pounds of alfalfa. To the alfalfa raiser who is fattening lambs primarily as a means of marketing hay, this method of fattening takes too many lambs and too much grain to market a ton of hay. Eight to ten lambs are required to market a ton of hay, and these lambs will cost approximately $6.00 a head. With this ton of hay, 600 to 750 pounds of grain will be required which, if purchased, will cost $10.00 to $15.00. This means an investment of $45 to $75 in order to market one ton of hay. To an alfalfa grower of limited financial resources, this large investment is a serious and often insurmountable obstacle.

### Lambs Ready for Market Too Early

A second drawback is that if the lambs are put on feed when they come off the range, they will be ready too early for the best market. The price of lambs normally increases from the time the last lambs come off the range in October or November until the time the earliest spring lambs come onto the markets from Southern Oregon.

### Prices Increase 52 Cents Per Month

During the last fifteen years, or since the Portland Stock Yards were established, the average increase in price of lambs from October until April has been 52 cents per hundred pounds per month, as is shown on the accompanying chart. This chart should be understood as an average of the fifteen years good and bad. Some years the market does not go up at all during the winter, while other years the increase is over $1.00 a month. Most of the feeder lambs come off the ranges in October, and if put on a grain ration at once will be ready to market in January; whereas the best price is not usually obtainable until April.

### New Method Necessary

This situation naturally raises several questions. First, could the lambs be fed for a longer period than 75 days, using the same grain but more hay, and figuring that the increased price obtained by holding the lambs for a later market would afford a reasonable return for the additional hay used? Second, how much more hay would be necessary? Third, will a lamb gain in either weight or finish on hay alone? Fourth, would it be better to feed a little grain each day for a longer time, or to feed hay alone for a while and then give a heavier ration of grain for finishing?

### Tests Planned at Umatilla

The tests conducted at the Umatilla Experiment Station during the winter of 1923-24 were intended to throw light on these matters. A car of average feeder lambs was used. All lots were to receive 75 pounds of grain per head, and all were to be fed for 150 days. Circumstances made it necessary to reduce the feeding period to 136 days, but each lamb received the 75 pounds of grain as was planned. The lambs in Lot 1 received their 75 pounds of grain evenly distributed throughout the entire time. Lot 2 received their 75 pounds of grain at the rate of ¾ pound per day during the last 100 days. Lot 3 received their 75 pounds of grain at the rate of one pound per day during the last 75 days, while Lot 4 received their grain at the rate of 1½ pounds during the last 50 days. All lots had all the hay they would eat all the time.

TABLE I. AVERAGE OF 1923-24 AND 1924-25 TESTS.

| Plan of feeding. | Lot 1 ½ lb. grain for entire time. | Lot 2 No grain first 50 days ¾ lb. grain last 100 days. | Lot 3 No grain first 75 days 1 lb. grain last 75 days | Lot 4 No grain first 100 days 1½ lb. grain last 50 days. |
|---|---|---|---|---|
| HAY ALONE | | | | |
| *Days fed | ............... | 41. | 65. | 87. |
| Wt. at beginning | ............... | 60.8 | 61.1 | 61.0 |
| Wt. at close | ............... | 63.7 | 64.7 | 64.8 |
| Gain per head | ............... | 2.9 | 3.5 | 3.8 |
| Gain per head per day | ............... | .07 | .06 | .05 |
| Hay per day | ............... | 2.6 | 2.7 | 2.6 |
| Feed cost per day | ............... | .0103 | .0107 | .0106 |
| **Total cost per day | ............... | .0192 | .0196 | .0195 |
| HAY AND GRAIN | | | | |
| *Days fed | 143. | 102. | 78. | 56. |
| Wt. at beginning | 60.9 | 63.7 | 64.7 | 64.8 |
| Wt. at close | 85.8 | 87.5 | 90.4 | 86.5 |
| Gain per head | 24.9 | 23.9 | 24.8 | 21.7 |
| Gain per head per day | .17 | .23 | .32 | .39 |
| Hay per day | 2.7 | 2.7 | 2.4 | 2.1 |
| Grain per day | .53 | .75 | .99 | 1.40 |
| Feed cost per day | .0187 | .0221 | .0246 | .0296 |
| **Total cost per day | .0276 | .0310 | .0335 | .0385 |
| BOTH PERIODS TOGETHER | | | | |
| *Days fed | 143. | 143. | 143. | 143. |
| Gain per head | 24.87 | 26.7 | 29.22 | 25.5 |
| Gain per head per day | .17 | .19 | .2 | .18 |
| Hay per day | 2.67 | 2.68 | 2.55 | 2.45 |
| Grain per day | .53 | .53 | .53 | .53 |
| Feed cost per day | .0186 | .0187 | .0183 | .0178 |
| **Total cost per day | .0275 | .0276 | .0272 | .0267 |
| Feed cost per 100 lbs. gain | $10.71 | $9.96 | $8.97 | $10.10 |
| **Total cost per 100 lbs. gain | $16.10 | $14.98 | $13.56 | $15.35 |

*On account of weather and other conditions, the length of the periods varied slightly from the schedule, but each lamb received exactly 75 pounds of grain.

**The total cost includes the feed cost plus the following items: Labor, $.005 per head per day; miscellaneous, including dip, salt, equipment and interest, $.0033 per head per day; and death loss, $.0006 per head per day.

### Tests Repeated

In the winter of 1924-25, this test was repeated, except that it was possible to feed the full 150 days as scheduled. The results of the two tests were practically the same, and the averages of the two are shown in Table I. From this table we are able to obtain quite conclusive answers to our original questions.

### Preliminary Hay Feeding Successful

First, we find that these small lambs were fed 2.63 pounds of hay a day, or about 80 pounds a month. This was all they would consume without undue waste. Other tests have shown that larger lambs will consume a larger quantity of hay. Second, the gain on hay alone was very small, averaging .06 pound a day, or about two pounds a month. This gain is so small that it might be all fill. Of course, with so small a gain, the lambs did not fatten. In other words, they were merely marking time while they were fed hay alone. The two pounds of gain a month will about pay for the labor and the incidentals, and we would, therefore, have to look to the increased price to pay for the hay. We have already seen that the normal increase during the winter months is 52 cents per hundred pounds, which, on an 85-pound finished lamb would amount to 44 cents a head. This would pay $11.00 a ton for the hay.

### One Pound of Grain Best Ration

In answer to the final question of whether the grain should be fed in large quantities during a short time, or in small quantities during a longer time, these two tests indicate that the standard practice of one pound of grain per head per day is better than either a larger or a smaller amount of grain, and it would therefore be our recommendation that the grain be fed at the rate of one pound per day beginning approximately 75 days before the time it is intended to market the lambs, unless the lambs are especially small and thin, in which case the grain feeding should cover 90 to 100 days. Likewise, if the lambs are already in good condition, the length of the grain feed can be reduced to 60 days. The lambs used in these tests were quite thin and did not reach a prime condition on 75 pounds of grain. The kind of grain, as shown in Oregon Station Bulletin 198, may be either barley, wheat, oats, or corn, or any mixture of these, and should be fed unground.

### Long Feed Practical

Taking all factors into consideration, we believe that it is quite practical for the alfalfa farmer to feed lambs for a while on hay alone, depending upon the increased market price to pay for the hay, and in the meantime postponing the feeding of grain until from 60 to 100 days of the time when he intends to market the lambs. The length of time which the lambs are fed on hay alone is entirely optional with the feeder, providing that the grain feeding begins at such time as will make the lambs ready for market not later than the middle of April. Early spring lambs may come at any time after this date and break the market. The length of time to feed grain depends partly upon the condition of the lambs and partly upon their size. A good fleshy feeder will fatten in 60 days, getting one pound of grain per day. A medium feeder will fatten in 75 days; while a thin feeder will require 90 days. Since the lambs should put on about ⅓ pound of gain a day while on grain, it is easy to figure what the size will be when finished. Lambs that weigh 90 pounds or more (stock-yards weight) always sell at a discount. It is better to sell the lambs before they are finished, than to risk keeping them until they are overweight.

### Lambs Must Be Small

We must warn the feeders, therefore, that only small lambs should be used for a long feed, and if they go much above 60 pounds in weight before the grain feeding is begun, by the time they are fat they will be too heavy to sell well.

### Fair Profits for Fifteen Year Average

Theoretically, if a lamb is bought for 10 cents a pound and kept for five months, we should expect the price to increase 52 cents a month, or a total of $2.60, making the probable selling price of the lamb $12.67 per hundred pounds. Lambs bought and sold on this basis and fed after the manner of Lot 3 of these tests, would return $8.00 a ton for the hay and $30.00 a ton for the grain, in addition to current wages for labor, incidentals, and interest on investment. In actual practice, the increase in price during the winter in good years is more than this, and in bad years less.

### Large Profits in Last Two Years

The two years in which these tests were conducted were good years. The first year, the lambs were bought at $10.00 per hundred at Pilot Rock and sold at Portland at $14.48 per hundred. The second year, the lambs were bought for $10.25 per hundred at Stanfield and sold at Portland for an average of $15.12 per hundred. The returns were, of course, proportionately larger. The actual price received for the hay in the first test was $17.87 for all the lambs on test, and $20.93 for Lot 3. In the second test the returns for the hay for all the lambs including some inferior lots not described in this Bulletin were $11.24. The returns on Lot 3 were $18.20. The first test was the more profitable in spite of a lower price, because the grain in that test cost $29.00 a ton and in the second test $43.75 a ton, and also because the lambs in the second test gained a little better. In planning for the future, it would seem wiser to base our estimates on the average increase in price for the past fifteen years rather than upon the price of the last two years.

### Waste Hay and Manure Add to Profits

In addition to the cash returns, there will be about 50 tons of manure for each car-load of lambs. There will also be the waste hay. From 10 to 20 percent of the hay will be refused by the lambs, but may be fed to stock cattle or horses. For this purpose, it has about one-half the value of good hay. In these experiments, 17 percent of the hay was refused in the first test and 15 percent in the second. The lambs are charged, however, with the total amount offered.

### Long Feed Requires Smaller Investment

Comparing this long feed with the short feed, we find the profits on the long feed less in the good years and more in the bad years, but averaging about the same. As a practical business proposition for the alfalfa farmer, however, the long feed is very much the safer and better on account of the lower investment and less risk. On a short feed it will take eight to ten lambs and 600 to 750 pounds of grain to market one ton of hay. This involves too much investment and too much risk for any farmer who does not have his farm free of debt and some ready cash on hand. On a long feed, however, the number of lambs and the amount of grain needed to market a ton of hay is cut in half. This halves both the investment and the risk and puts the business within the reach of any alfalfa farmer who is in reasonably sound financial condition.

### Long Feed Better for Bankers

A bank may safely lend the entire purchase price of the lambs on a five months feed, and if the feeder is an exceptionally good man, the banker may even furnish the money for the grain. He can not, however, on a short feed safely lend the price of the lambs, to say nothing of the price of the grain.

### Farmers Can Compete with Commercial Feeders

A large proportion of the lambs fattened in the Northwest are fattened by commercial feeders at Portland and other central points. These feeders get their grain at as cheap a rate as the alfalfa farmer, but their hay is baled and shipped to them and is, therefore, much more expensive. These feeders have a considerable advantage over the alfalfa farmers in crowding lambs through rapidly for an early market. On the other hand, the alfalfa farmer has a decided advantage in feeding for the late market.

### Fall Pasture for Fattening Lambs

It is a rather common practice in some localities to run lambs on the last cutting of alfalfa, meadows, stubble fields, etc., as long as weather will permit before putting them in the feed lot. As a check on this practice, a fifth lot of lambs similar to the four already described were kept on such pasture for 57 days, and then fattened on grain the same as were Lot 3. These lambs on pasture made a little better gain than those on hay, but not very much, and they did not get fat. Such pasture should be considered in the same light as feeding hay alone; that is, it will hold the lambs for a later market and returns for such pasture will be obtained only from an increased price. If the lambs are weighed when they come off good pasture, care should be taken not to be deceived by the fill.

### Pasture Gains Small but Profitable

Our lambs gained only 7.3 pounds per head during the 57 days they were on pasture and it is probable that some of that was fill. The normal increase of 44 cents a head in market value would be a reasonable price for the pasture. The customary rental of such pastures is considerably less than this, but there is always some danger of loss from bloat.

### Lambs Fatten Only on Grain

The use of such fall pastures for holding lambs for a later market is a desirable practice, providing the feeder realizes that it is only a holding proposition and that the lambs will not begin to get fat until they are fed grain.

Fifty tons of hay on way to market. Lambs fed at Umatilla Branch Experiment Station enroute to railroad.

Finished lambs at Portland stock-yards.

Station Bulletin 219 September, 1925

Oregon Agricultural College

Experiment Station

# Cost of Producing Mutton and Wool on Eastern Oregon Ranges

By

E. L. Potter and H. A. Lindgren

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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Fig. 1. In winter quarters.

## SUMMARY

With wool at 40c, the cost of producing feeder lambs is $9.24 per hundredweight.

With wool at 40c, the cost of producing early fat lambs is $9.90 per hundredweight.

With fat lambs at $10.50, feeders at $10.00, fall prices, and wool at 40c, sheep are paying $8.00 a ton for hay, $1.62 a year for grass, wages, and 8 percent on the livestock investment.

The cost of producing lambs for the winter market increases 50c per hundredweight for each month after the grazing season is past.

# Cost of Producing Mutton and Wool on Eastern Oregon Ranges

By

E. L. Potter and H. A. Lindgren

This bulletin aims, first, to present a fair picture of the financial status of the sheep business in Eastern Oregon; second, to show simple methods of estimating costs of production which will enable the producers to figure out their own costs more accurately; and third, to point out the financial importance of certain management practices and thus lead the way towards cheaper production and greater returns.

This bulletin is the result of several years of study and investigation, and the data have been discussed with most of the leading sheepmen of the state. The cost tables were presented before the 1925 meeting of the Oregon Wool Growers' Association at Pendleton, and also before the 1925 meeting of the National Wool Growers' Association at San Francisco. They have also been presented to and discussed by small groups of sheepmen in various parts of the state.

**Two types of sheep raising.** There are two distinct methods of handling ewes in Eastern Oregon; one method is for early lambs, and the other is for late lambs. By early lambs we mean lambs that are dropped while the ewes are still on hay and before grass comes. These usually will be marketed as fat lambs directly from the summer range. By late lambs we mean lambs not dropped until the ewes have gone out on the range. Such lambs are marketed in the fall. The early lambs are mostly sired by Hampshire or other black-faced rams, and out of cross-bred ewes. The most popular cross-bred ewe is a Rambouillet-Lincoln cross, but such ewes actually run to all mixtures of mutton and fine-wooled breeding. The late lambs are mostly sired by Rambouillet rams and out of ewes carrying a considerable percentage of Rambouillet or Delaine blood. In the case of early lambs, both ewes and wethers are generally sold for mutton, while in the case of late lambs of Rambouillet or Delaine breeding, the ewes are generally kept for breeding purposes. Rambouillet wether lambs sell for less money than Hampshire wether lambs, but Rambouillet ewe lambs bring a premium over Hampshire ewe lambs.

The choice between early and late lambs depends upon many factors. (1) Early lamb production is not practical unless the summer range is of such quality that the lambs will get fat enough for market before they leave the summer range. (2) The summer range must be near enough to a railroad so that the ewes and lambs can be trailed to the loading point without the lambs losing too much weight. It is customary to wean these lambs at the railroad; that is, they do not leave their mothers until they are driven onto the cars. Plenty of good alfalfa is also necessary, as ewes cannot be lambed on hay if the hay is limited in amount or poor in quality. The southern Idaho district, accessible to the big alfalfa fields of Snake River valley, is almost altogether an early-lamb district. The Blue Mountain sections of Oregon, within fifty miles of a railroad, are largely, but by no means entirely, early-lamb districts, while the more distant portions, together with Central and south-central Oregon, are largely devoted to late lambs. The dividing line, however, is not very well marked and many sheepmen in the northeastern part of the state produce both early and late lambs.

**The production of late lambs.** Since the raising of late lambs is the older and really the foundation industry, it will be studied first.

COST AND INCOME

| **Expenses** | | **1200 Head** | **Per Head** |
|---|---|---|---|
| 1 herder for 12 months at $100 (including board) | | $ 1,200.00 | $1.00 |
| ½ camp tender 12 months at $120 (1 camp tender for 2 bands) | | 720.00 | .60 |
| Extra help at lambing (2 men 2 months at $90.00) | | 360.00 | .30 |
| Interest, upkeep, and depreciation on camp tender outfit and miscellaneous | | 360.00 | .30 |
| Shearing and packing wool | | 300.00 | .25 |
| Cost of summer and winter range: | | | |
| Interest on 3 acres winter range (5 percent on $7 per acre) | $1.05 | | |
| Taxes on 3 acres at 11 cents | .33 | | |
| Free range, 2½ acres | | | |
| Summer range, two-thirds National Forest and one-third leased land | .24 | 1,944.00 | 1.62 |
| Hay, 250 pounds per head at $8 per ton | | 1,200.00 | 1.00 |
| Ram service | | 240.00 | .20 |
| Taxes | | 180.00 | .15 |
| Interest at 8 percent on average value of $8.44 | | 810.24 | .68 |
| Losses at 10 percent, 120 head @ $8.44 | | 1,012.80 | .84 |
| Depreciation at $1.17 on 1080 head | | 1,260.00 | 1.05 |
| Total expenses | | $ 9,587.04 | $7.99 |
| **Returns** | | | |
| 960 lambs weighing 65 pounds @ 10 cents | | $ 6,240.00 | $5.20 |
| 9600 pounds wool at 40 cents | | 3,840.00 | 3.20 |
| Total returns | | $10,080.00 | $8.40 |

Note: Death loss and depreciation may be made up by buying enough yearling ewes each year to keep the ewe band up to standard. The cost of such replacement should be as shown below:

| | | |
|---|---|---|
| 256 yearling ewes @ $11.00 | $ 2,816.00 | |
| Credit by 136 old ewes sold at $4.00 | 544.00 | |
| Net cost | $ 2,272.00 | $1.89 |

It will be noted that the final cost of replacement is the same as the combined figure for losses and depreciation previously given.

**Labor.** The labor costs given are quite typical of most of the sheep country, and the monthly wages include board, which will generally run close to $1.00 a day. It must be borne in mind, however, that many sheepmen are obliged to have one camp tender for each band, at least in the summer time. The extra help at lambing is the most variable item, but the figure given is about an average of the general practice. There are men with exceptional equipment and facilities who are able to lamb with half of the labor quoted, but such instances are rare. There are a great many outfits that have to have twice as much labor as has been indicated.

**Grazing.** Averaging together all of the sheep in Eastern Oregon, the grazing cost would be about as given in the table, or $1.62 per head. In actual practice the cost of grazing is never twice the same. Some ranchmen own nearly all their range and some own very little. Some have paid $10.00 to $12.00 an acre and others less than $5.00. Where all the range is leased, there would be about seven months of summer range at 15 cents a month, two months of fall grazing on the meadows and fields at 30 cents a month, making a total of $1.65 a month; this may be taken as a fair average cost of grazing, at least when we consider any large number of outfits. There are perhaps outfits whose grazing costs would not exceed

$1.00; on the other hand, there are a great many outfits that have invested heavily in high-priced land and whose costs will run more than $2.50 per head. Neither of these cases, however, can be considered as typical, and the latter often includes land bought for speculative purposes rather than for grazing.

The valuation of $7.00 an acre given to the winter range is an arbitrary figure, but represents our best judgment as to the present market value of average Eastern Oregon deeded range. It also represents a fairly reasonable capitalization of its earning capacity. The interest rate is figured at 5 percent, since we cannot very well expect land to return an interest rate much different from that paid by the best grade of bonds and other long-time conservative investments. This valuation, however, would not be possible if the deeded range were not supplemented by free range or National Forests where the grazing is relatively cheaper than on the deeded lands. The average sheep of Eastern Oregon grazes an area of 10 acres. This total area will pay taxes and interest on about $27.00, or $2.70 an acre.

Fig. 2. Springtime. Land of this type is nearly all under private ownership.

**Hay.** The amount of hay required to winter sheep is exceedingly variable, and there is not the uniformity of practice as in the case of cattle. Not only does practice differ greatly in different localities, but it is not at all uncommon for the consumption of hay to be twice as much one winter as it is the next; in fact, on mild winters sheep will often winter out without hay and perhaps the next winter require 400 pounds per head. The gradually increasing number of stock on our ranges, combined with the deterioration of the ranges themselves, has led to a constantly increasing amount of hay required for winter. On the average, 250 pounds per head, or as it is commonly expressed, "125 tons per thousand," is probably about typical where the ewes do not lamb until after they go on grass. The price of the hay has varied greatly in recent years and will probably continue to vary. It is our judgment that $8.00 a ton represents about the average cost of production, allowing a reasonable interest on the investment, etc. Our observations teach us also that a price much less than $8.00 discourages production to the point where we soon have a shortage, while a price much above $8.00 encourages production to the point where we soon have a surplus. Until economic conditions change, therefore, we believe it safe to figure $8.00 as a fair and reasonable valuation for alfalfa hay in the stock districts, recognizing, however, that close to railroads it will have a somewhat higher value than this, often high enough in fact to prohibit its use by the range stockmen.

A separate charge for feeding hay is not made since the herders and camp tenders usually do that.

**Taxes.** The average assessed valuation of all sheep in Eastern Oregon for the years 1923 and 1924 was $5.55 per head. The average levy, exclusive of city taxes, was approximately 2.7 percent. This gives a tax of 15 cents per head.

**Depreciation and losses.** It is generally estimated in the range districts that a ewe will not produce more than six crops of lambs and that the annual death and stray losses are approximately 10 percent. In actual practice, there are three ways of meeting losses and depreciation. First, a man may buy a band of yearling ewes and run them as long as possible and then sell the remainder. In this case the financial statement should show a constant marking down of the ewes, since a band of yearlings which would cost around $15,000 at the beginning would, at the end of six years, be worth not over $3,000. Second, he may retain a portion of the ewe lambs, carrying them over for a year and putting them into the breeding flock at the age of about eighteen months. In this case, he must add to the expense bill, instead of loss and depreciation, the cost of maintaining these extra yearling ewes; while on the receipt side, he must subtract the value of the ewes kept and add the value of the cull ewes sold. The balance sheet will then be very much the same as that given above. A third method, and the one which is quite common in districts producing only early lambs or among small operators handling only one band, is to cull out each fall the old and undesirable ewes and then buy enough yearling ewes to make up for the death losses of the year just passed and for the cull ewes that have been taken out.

On the basis of six crops of lambs per ewe and an annual death loss of 10 percent, a theoretical flock would consist of the following at breeding time:

| *Number of head* | *Percentage* |
|---|---|
| 256 yearlings | 21.3 |
| 230 two-year-olds | 19.2 |
| 208 three-year-olds | 17.3 |
| 187 four-year-olds | 15.6 |
| 168 five-year-olds | 14.0 |
| 151 six-year-olds | 12.6 |
| Total 1200 ewes of breeding age | 100.00 |
| 136 cull ewes taken out | 11.3 |

It will be seen from the above that in order to maintain a band of 1200 ewes, it would be necessary to buy each fall about 256 head of yearling ewes, and to sell 136 culls. In our expense account $1260 has been allowed for depreciation and $1012.80 for losses, or a total of $2272.80. Suppose that to this $2272.80 was added the receipts from 136 cull ewes at $4.00 a head, or $544.00; this would give a total of $2816.80 with which to buy 256 yearling ewes at $11.00.

The estimate of $1.00 for depreciation and 10 percent for the losses is the figure in very common use at present among the Eastern Oregon sheepmen. Our studies, however, indicate that this is a little low. If a yearling ewe is worth $11.00 and at the end of six years is worth only $4.00, the depreciation would be $1.17. This depreciation can be properly charged only against the ewes that live and not against those that are lost. In this particular case it is charged against the 1,080 ewes remaining at the end of the year rather than on the 1,200 ewes with which the year was started. If charged against the entire 1,200, the depreciation per head would be $1.05 instead of $1.17. The stockman's practice of estimating depreciation at $1.00 per head on the entire band, therefore, works out all right, even if it is not mathematically absolutely accurate.

Fig. 3. Summer-time in the National Forests.

From the standpoint of building up a good band of ewes, there are many advantages in retaining the ewe lambs rather than in buying yearlings, and this practice is very strongly recommended for farm flocks. On the range, however, this may not always be practical. The operator, for example, who has range for only one band of ewes may find a small bunch of 200 or 300 yearlings very much of a nuisance and in this case the raising of the yearlings had best be left to the man who can handle enough to make up a straight yearling band. Also, in the early-lamb districts, the big black-faced ewe lambs produced there will be both more expensive and less desirable than the Rambouillet ewe lambs from the late-lamb districts.

**Interest.** In these estimates the ewes are valued at $8.44 a head. This is the average value of the ewes of breeding age where the yearlings are worth $11.00 and the culls $4.00, allowing for the fact that on account of death loss there are more young ewes than old ewes. These values are based as nearly as possible upon the cost of production rather than upon current market values. In the long run, the value of a ewe must be the market value of the ewe lamb plus the cost of keeping her until she is of breeding age. Any other valuation must be temporary.

Interest on the ewes is figured at 8 percent, the standard bank rate in most localities. While it is true that loan companies often charge 9 and 10 percent, such a high rate of interest seems prohibitive for the sheep business. Furthermore, we feel that most sheepmen would be very well satisfied to receive 8 percent on their livestock investment.

All of the above estimates have been made upon the basis of six lamb crops per ewe. With good ewes under good care this may reasonably be expected, but there are many cases in which the ewes do not last this long. With ewes having a high percentage of mutton blood but a small percentage of fine wool blood, it is often difficult to get an average of more than five lamb crops. Likewise, ewes that are run in a sandy country wear out their teeth rapidly and must be discarded at an early age. Ewes wintered on the sands of the Columbia river do not produce much more than four lamb crops.

Some sheepmen keep their ewes until they die and then sell the pelts, but this is not the general practice. It is also possible to get one or two extra lamp crops out of worn-out ewes by wintering them on chopped hay and a little grain, and summering them on irrigated pastures. This has been profitable when sheep and wool are high, but not when prices are low.

**Ram service.** The cost of ram service per ewe in this estimate is figured at 20 cents. This is for a ram costing $25.00 as a yearling, and worth for mutton $2.50 at the end of four years' service. In this case the annual depreciation would be $5.63; interest at 8 percent on his average value, $1.32; insurance or death loss, $1.32; labor, $2.00; pasture charge, $2.00; hay, $1.60; shearing and marketing wool, $0.25; taxes, $0.17; or a total annual cost of $14.29. The ram should shear 10 pounds of wool worth $0.40 which amounts to $4.00. Subtracting this from the total cost, leaves a net cost of $10.29 for the year. If the ram is used on 50 ewes, the cost per ewe amounts to $0.20. It seems hardly practicable to use a ram costing less than $25.00 as a yearling, and usually the cost will be higher rather than lower.

**Returns.** Returns are for lambs figured on the basis of 80 lambs for each 100 ewes bred. This means a lamb crop of about 90 percent when we allow for the death of some ewes before lambing time and for the death of some lambs after marking time. This is probably better than the average for the state but is about correct for the bands that receive reasonably good management. Returns for wool are figured at 8 pounds, which is the average for the state. It is quite true, however, that some of our range men have, by careful selection, increased this figure to 12 or 14 pounds.

**The raising of early lambs.** In the handling of early lambs, the general items of expense are practically the same as for late lambs, but approximately double the amount of hay is required, together with some investment in sheds for lambing time. This is compensated by a somewhat larger lamb crop, heavier lambs, and usually a better price. Estimates are based upon 5 percent more lambs, 10 pounds per head more weight, and 50 cents per 100 pounds better price. Where conditions are reasonably favorable for early lambs, they are usually more profitable than late lambs, but this will depend much upon local conditions. There is ample room for both practices and no general change seems necessary.

A typical budget is as follows:

| | | |
|---|---|---|
| **Expenses.** | | |
| Expenses as for late lambs | $ 9,587.04 | $7.99 |
| Additional hay, 250 lbs. per head @ $8.00 | 1,200.00 | 1.00 |
| Interest and depreciation on sheds (15 percent on $4,000) | 600.00 | .50 |
| Total expenses | $11,387.04 | $9.49 |
| **Returns.** | | |
| 1020 lambs weighing 75 pounds @ $10.50 | $ 8,032.50 | $6.69 |
| 9600 pounds of wool @ 40 cents | 3,840.00 | 3.20 |
| Total returns | $11,872.50 | $9.89 |

Fig. 4. Sheds for early lambing (Jos Cuhna, Echo).

It should not be assumed from the above that merely supplying 250 pounds more hay and the building of a lamb shed will convert a range suitable to late lamb production into a range upon which early lambs will be profitable. Likewise, it must not be assumed that on a range essentially suited to the production of early lambs, a change to late lambs would reduce the hay required by 250 pounds and eliminate the necessity of lambing sheds. As a rule, the early lambs are produced in the more mountainous districts having a greater variety of summer feed and more alfalfa, but often a longer winter. The late lambs, on the other hand, are generally produced in the areas having a less satisfactory summer feed and less hay for winter, but a milder and more open winter with more winter range. The valleys of the Blue Mountains run more largely to early lambs, while Central and southeastern Oregon run more to late lambs.

The business of raising early lambs is comparatively new, and the past few years have seen a very considerable shifting from late lambs to early lambs. This movement, however, seems to have gone far enough. At first the early lamb producers had a marked advantage over their rivals, but the large development of the early lamb business, especially in Idaho and Washington, has made feeder lambs and ewe lambs for breeding purposes relatively scarce, and has thereby put the late lamb producers of Central and south-central Oregon in a strong position. Any change from early lambs to late lambs or vice versa should at the present time be made only upon the basis of the adaptability of the range and not on the assumption that either form of the sheep industry is inherently more profitable than the other.

**Profits and losses.** Financially, the budgets given mean that a band of sheep should return to the owner $8.00 a ton for the hay, $1.62 for range, 8 percent on livestock investment, current wages for labor, and about 40 cents a head additional. If he owns the ewes outright, grows his own hay, owns his own pasture, and does his own labor, all of these various items mentioned will come into his own pocket. On the other hand, if he borrows the money to buy the ewes, buys the hay, rents the range, and hires the labor, all that will be coming to him will be the 40 cents a head. The probabilities are that under these circumstances his management will not be very good, and he will not even get the 40 cents.

It should be remembered that the above costs are all for lambs sold in the summer or fall. Any lambs kept into the winter after grass is gone must be fed hay or hay and grain, in which case the cost will be increased 50 cents per hundredweight for each month that the lambs are held. (For details of winter feeding, see Oregon Experiment Station Bulletin 218, Fattening Lambs for the Late Winter Market.)

The above is for average conditions. There are always possibilities of doing better than average, and equal possibilities of not doing as well. It is true that large profits are often made through investing when prices are low, and likewise large losses often occur from investing when prices are excessively high, but in the long run success depends upon efficient management. The more important points of management which seem to have a bearing upon profit and loss in Oregon are as follows:

1. The size of the band and the number of bands should be such as to insure efficient operation. Usually about 1200 ewes can be handled satisfactorily. Too large a number will result in heavy losses and a smaller lamb crop, while too small a number makes the overhead too heavy. Ordinarily where one camp tender can take care of two bands, the two-band unit is the more efficient, although there are many very economically managed one-band units in which the owner takes care of the camps and looks after various miscellaneous items. Large outfits of four or five bands or more are seldom so efficiently handled; the owner has difficulty in keeping in personal touch with all of his operations, with the result that the work is poorly done and the expense bills too high. Also, too much time and money are spent in travel.

2. Inadequate finances often lower the profits, partly in that the man with limited means cannot do the things which he knows should be done,

partly because too much of the management is in the hands of the bank or loan company, and partly because the interest rates are too high. If the owner has an equity of 50 percent or more in the entire plant, including both sheep and land, he should be able to borrow the remainder at an interest rate of not over 7 percent, especially if most of it is borrowed on the land. On the other hand, if his equity is much less than 50 percent, he will probably have to pay 9 to 10 percent interest and this will, of course, absorb any reasonable profits which he might make. A 75 percent equity in a one-band outfit is much better than a 25 percent equity in three or four bands.

3. A large lamb crop has been the key to the success of many of our better sheep operations. Lamb crops of 60 and 70 percent are entirely too common. Most of these are due to carelessness in culling the ewes, not enough good rams, dry feed at breeding time, or insufficient care at lambing time. It is our judgment that the sheepman who does not get an 85 percent lamb crop or better will eventually be unable to stay in the business. The size of the lambs at marketing time is as important as the number, and big, fat lambs are the result of good bucks and of plenty of green feed throughout the season. Of course, it is not always possible to have feed conditions ideal, but most of the poor lambs are the result of poor bucks or careless herding, or both.

4. One of the greatest opportunities for increased profit lies in the increased wool crop. The progress that has been made by the sheepmen of America in the last seventy-five years in increasing the wool clip is remarkable. Seventy-five years ago the average wool clip was less than 4 pounds per head. Today it is almost 8 pounds, and in Oregon more than this amount. The process of improvement is still going on. The Oregon Agricultural College Extension Service, in its Wool Improvement Campaign, has demonstrated that by careful culling of the ewes, combined with the use of heavy shearing bucks, a wool clip of 12 pounds and more on large bands is an actual possibility. These large wool clips have been obtained with no sacrifice of the lamb crop; in fact, the heavy shearing bands of the state are producing more than an average lamb crop. What these additional pounds of wool mean to the profits is easily seen, and it has been obtained with no expense other than a few days' careful work once a year.

On the whole, sheep raising is like any other industry; merely being "in the sheep business" does not mean either profit or loss. As in any other business, success depends upon the intelligence and efficiency with which the business is conducted. The sheep business, during the recent depression, however, has had an advantage over nearly all other phases of agricultural production in that its total production has been below rather than above normal. While beef and pork have been so abundant that they can be sold only at sacrifice prices, lamb has been scarce enough to be in the luxury class. Likewise, wool production is enough below domestic consumption to give the sheepman the advantage of a protective tariff and to relieve him of the necessity of depending upon a demoralized European market.

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Note: Since this bulletin was begun, Oregon has put her average clip over the 9-pound mark. This is the first and only time that the U. S. Department of Agriculture has credited any state with a wool clip of over 9 pounds.

Station Bulletin 220 November, 1925

Oregon Agricultural College

Experiment Station

# Cost of Producing Beef on the Ranges of Eastern Oregon

By

E. L. POTTER

1885

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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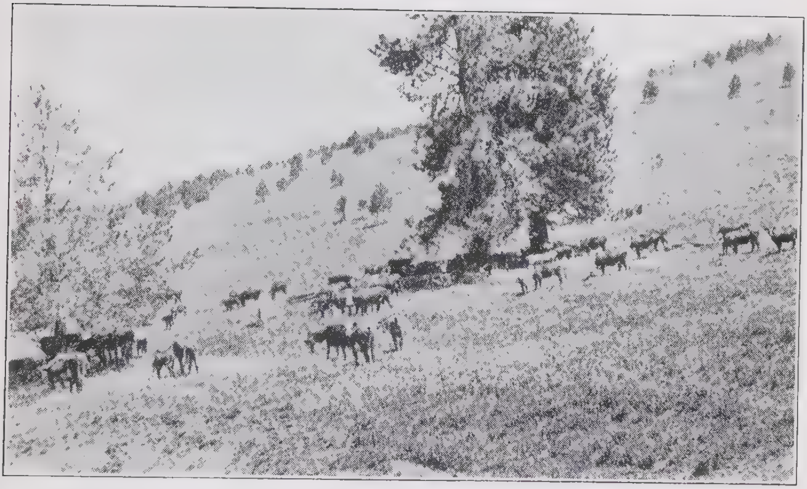

Fig. 1. Beef cattle on range in Eastern Oregon.

## SUMMARY

| | |
|---|---|
| Cost of grass steers per 100 pounds, live weight, farm price | $ 9.75 |
| Cost of winter fed steers per 100 pounds, live weight, farm price | 11.50 |
| Cost of beef cows per 100 pounds, live weight, farm price | 8.00 |
| Cost of weanling calves per 100 pounds, live weight, farm price | 9.27 |
| Cost of yearlings per 100 pounds, live weight, farm price | 8.70 |
| Cost of running a breeding cow a year | 27.10 |
| Cost of running a mixed herd a year | 21.40 |

# Cost of Producing Beef on the Ranges of Eastern Oregon

By

E. L. Potter

Interest in the cost of producing beef lies primarily in a desire to forecast the future rather than in mere curiosity in what is past and gone. The studies and investigations which have led to the publication of this bulletin have, therefore, been directed more toward the fundamental economics of beef production than to mere bookkeeping. The particular aim has been to determine the factors which enter into the cost of beef production; that is, the amounts and kinds of feed, labor, grass, taxes, etc., necessary to the production of 100 pounds of beef. Once we have a knowledge of these facts, we then need only a list of current market prices to enable us quickly to determine the final cost of producing 100 pounds of beef in any given instance.

These cost studies may also bring out the financial importance of certain management practices that might well be improved. Lastly, this bulletin attempts to present a fair picture of the financial side of the beef cattle industry.

This bulletin is based partly upon surveys of the cattle industry in Oregon made at various times during the past ten years, and also upon a long series of experiments in growing cattle under range conditions conducted at the Eastern Oregon Branch Experiment Station. The first report on this work was made to the Oregon Cattle and Horse Raisers' Association at their annual meeting in La Grande in 1917. Since that time, however, the work has been checked and rechecked and hundreds of additional cattlemen interviewed. It is believed that the figures as they now stand are reasonably accurate.

**The Blue Mountain section.** Since beef cattle are produced under a great variety of conditions, an attempt to discuss all of them at once would lead only to confusion. Hence various sections of the state are discussed one at a time, beginning with that part of Oregon generally known as the Blue Mountain section, including not merely the Blue Mountains themselves, but the adjacent hills and valleys. The region along the eastern slope of the Cascade Mountains and also considerable portions of Jackson county have conditions so similar that they could well be included in the same category. The discussion of the Blue Mountain section, therefore, includes all of Eastern Oregon except the free range areas of Malheur, Harney, Lake, and Crook counties, in which conditions are so different as to require separate discussion. The Blue Mountain secton is a country of the small cattleman. Most of the bunches run from 100 to 200 head. There are no outfits with more than 2,000 head and very few with more than 500. Both the ranges and the home ranches are for the most part too small to support large outfits. Much of the country is rough, and many ranches will have a difference in elevation of 500 to 2,000 feet between the highest and lowest points.

The typical system of handling is about as follows: The cattle are wintered on the home ranch, where they may get a little grass, but for at least four months, hay is the chief feed. In the spring the cattle are run out on the foot-hills and sage-brush lands adjoining the valleys, where they stay for one or two months. These foot-hill and sage-brush pastures are nearly all under fence and ordinarily form a part of the home ranch. For four to six months during the summer the cattle are on the mountains, either on the National Forest or on land leased from the timber companies. A few cattle may be kept on the foot-hill and sage-brush ranges throughout the summer, but this is not the general practice. In the fall the cattle are kept from one to two months either on the foot-hills and sage-brush land which they occupied in the spring, or on the meadows which produced a crop of hay during the summer. This completes the yearly cycle.

Fig. 2. A typical Blue Mountain ranch. Feed racks, alfalfa, and spring range.

Since most of the cattle trading is done in the fall, the cost figures have used that as a starting point in determining interest charges and inventories. Most of the spring calves are weaned in the fall, and it is not generally customary to count the calves in the inventory until after they are weaned; also most of the steers are sold at this season. Consequently, the fall makes a convenient beginning and ending point for the fiscal year.

Costs are of two kinds: First, operating expenses, such as labor, equipment, taxes, water-rights, fence repair, farm grazing fees, and salt. Second, investment expenses, including interest on both the investment in cattle and the investment in grazing-land. These two classes of expenses are separated because the first class is always a cost and one which must be met in all cases, while the second class represents a return on the investment rather than a true cost. Also the value of this investment is commonly obtained by capitalizing the income. Hence there is an inevitable tendency to mark up the value of the investment when cattle prices are good.

In this territory, most of the cattle are kept on the same ranch from birth until ready for market. Since cows, calves, yearlings, and two-year-olds are all run together as one herd, it is much simpler not to separate the cattle of different ages, but to consider the breeding herd as a whole, starting with the fall count. In making the inventory the spring calves only, are counted, and not the two-year-old steers and surplus dry cows, which are either already sold or ready for sale. Under these conditions the typical expense bill would be as follows:

COST OF RUNNING A MIXED HERD IN THE BLUE MOUNTAIN COUNTRY

October to October

| | | |
|---|---|---|
| **Running Expenses** | | |
| Hay for winter, 1 ton at $8.00 | $ 8.00 | |
| Cost of feeding hay, at $1.00 per ton | 1.00 | |
| Bull costs | .65 | |
| Salt | .25 | |
| Riding and putting out salt | 1.50 | |
| Taxes on cattle at 86c per head | .86 | |
| Taxes on 8 acres grazing-land at 11c per acre | .88 | |
| Forest grazing fees, 5½ months at 12c | .66 | |
| Total running expenses | | $13.80 |
| **Investment Expenses** | | |
| Interest on cattle, 8% of $60.00 | $ 4.80 | |
| Interest on 8 acres of land at $7.00 an acre at 5% | 2.80 | |
| Total investment expenses | | 7.60 |
| Total all expenses | | $21.40 |

Having presented the expense bill as a whole, the next step is to analyze the various items and see how they are determined.

**Hay.** The amount of hay for wintering is commonly estimated at 1 ton per head for mixed bunches. In some of the higher valleys that have rather long winters, such as those near Baker, Union, or Enterprise, the tendency is to feed more hay than this, probably averaging 1¼ tons. On the other hand, in the districts of lower altitudes and better spring and fall ranges, the amount of hay may be less than 1 ton. Throughout much of the Blue Mountain country, however, particularly Grant county and Wheeler county and some of the adjacent territories, there is scarcely enough hay raised to allow 1 ton per head for the beef cattle, after taking care of the other livestock.

The hay situation in Eastern Oregon is illustrated by the accompanying table which shows the hay in the country available for cattle in normal years after allowance has been made for horses, sheep, and dairy cattle. In this it will be noted that the counties producing much more than one ton of hay per head have a surplus which may be shipped to market, used for winter fattening, or perhaps used for wintering stock brought in from other counties. Each county of Eastern Oregon ordinarily feeds its own stock except that Morrow county winters a good many in Umatilla county and Harney sometimes winters a few in Malheur.

| County | Tons of hay per head of cattle | Remarks |
|---|---|---|
| Baker | 1.34 | Exports hay |
| Crook | .96 | |
| Deschutes | 1.54 | Exports hay |
| Gilliam | .54 | Feeds some straw |
| Grant | .62 | Some winter range |
| Harney | .87 | Some winter range |
| Jackson | 1.09 | |
| Jefferson | .72 | |
| Klamath | 1.27 | Some fattening |
| Lake | 1.45 | Some fattening |
| Malheur | 1.23 | Exports hay |
| Morrow | .53 | See Umatilla county |
| Sherman | .55 | Feeds some straw |
| Umatilla | 1.33 | Exports hay |
| Union | 1.53 | Exports hay |
| Wallowa | .74 | Short of hay |
| Wasco | .68 | Some straw |
| Wheeler | .67 | Some winter range |
| Total for Eastern Oregon | .99 | |

The cost of hay is figured at $8.00 a ton, which seems to be a fair price for the beef-producing districts. A price of less than $8.00 a ton has the effect of discouraging production and reducing the acreage of alfalfa, while a price much more than this figure has the contrary effect. We have made no complete survey of costs of hay production throughout the beef-producing sections, but upon the basis of such surveys as have been made and upon the work of the Union Experiment Station, the itemized cost of one ton of alfalfa would be as follows:

| | |
|---|---|
| Irrigation | $2.50 |
| Harvesting | 2.25 |
| Cultivating and occasional reseeding | .50 |
| Taxes on land | .65 |
| Interest on land at 5% | 2.00 |
| Total per ton | $7.90 |

There are, of course, certain districts with very high water charges that cannot meet this price. There are also other districts, close to a railroad, that can obtain a better price by shipping their hay to Portland. These districts, however, are outside of the cattle country and are not really factors in beef production.

**Feeding hay.** On account of the fact that labor in the winter is not well employed and that there is no demand for horse labor, it is customary to allow a much lower price for the use of a man and team than at other seasons of the year. We, therefore, find it common among cattlemen to estimate the value of a man and team during the winter at $3.00 per day, whereas in the summer it would probably be nearly twice that. Another factor is that the team does not work very hard and is fed almost exclusively on hay. Most of the stock cattle are fed on the meadows or pastures very close to the stack yards, and are fed on the ground rather than in racks. In this way one man and team can feed 300 to 400 head of cattle or about 3 tons of hay per day. From this we derive the customary figure of $1.00 per ton for the labor of feeding hay to stock cattle. This is also the most common price where the feeding is let by contract.

**Bull charges.** The laws of Oregon require, on the public ranges, one bull to each 25 cows. The actual practice is a few less than this although some of the best cattlemen use one to 20. In a small, fenced pasture one to 40 or 50 is enough. With good management the average period of usefulness of a bull is four years, after which time he will have to be sold for beef. Assuming that he would bring for beef about $60, the following table will show the approximate cost of maintaining a bull under various conditions.

| | | | | | |
|---|---|---|---|---|---|
| Cost of the bull | $100.00 | $200.00 | $300.00 | $400.00 | $500.00 |
| Depreciation | 10.00 | 35.00 | 60.00 | 85.00 | 110.00 |
| Average valuation during period of use | (85.00) | (147.50) | (210.00) | (272.50) | (335.00) |
| Interest at 8% and insurance at 5% on average valuation | 11.05 | -9.17 | 27.30 | 35.43 | 43.55 |
| Running expenses and range as other cattle | 15.95 | 15.95 | 15.95 | 15.95 | 15.95 |
| Total yearly cost | 37.00 | 70.12 | 103.25 | 136.38 | 169.50 |
| Cost per cow 1/50 | .74 | 1.40 | 2.06 | 2.73 | 3.39 |
| Cost per cow 1/40 | .93 | 1.75 | 2.58 | 3.41 | 4.24 |
| Cost per cow 1/25 | 1.48 | 2.80 | 4.13 | 5.46 | 6.78 |

The annual cost for one $100 bull per cow would be $1.48 per cow, or if charged to the entire herd, would be 44 percent of this figure or 65c per head, since a mixed herd carrying the steers to two-year-olds will run about 44 percent cows.

**Salt.** The actual salt required by cattle will range from ⅔ pound a month on dry feed to 2 pounds a month when on very green feed. If there is much waste the amount allowed should be increased enough to cover this; generally speaking, 16 to 20 pounds per annum will be sufficient. The cost probably will be less than 1 cent per pound in quantities at railroad points, but in smaller quantities at the ranch the cost will be 1¼ to 1½ cents per pound. The cattlemen generally estimate the cost of salt at approximately 25 cents per head per annum, which would seem to be a fair price, excluding the cost of putting the salt out on the range, which may be considered as a riding charge.

**Riding.** The expenses of riding are perhaps the most variable and the most difficult to estimate of all expenses connected with the cattle business, but fortunately the total of the item is not large. Where cattle are run together cooperatively and on the National Forest, riders are commonly hired by the association and the expenses prorated according to the number of cattle handled. We have the data for a large number of associations handled in this way and the average of all of these is 30 cents for the summer season of 5½ to 6 months. Sometimes the expense for the summer season is as little as ten cents and in other cases as high as eighty cents. The difference comes in the number of cattle handled and in the amount of riding done. Frequently the cattle are turned loose and no attention is given them other than rounding up and salting. Riding after the cattle while they are on the summer range is the smaller part of it since in addition to the expenses incurred through the association there is the necessary riding in rounding up and moving the cattle to and from the different ranges. This will involve much labor for a few days and then it is over for several months. The cost, of course, depends largely upon the distance traveled and the attention given. Generally speaking, however, cattle that are close at hand and easy to see are given very much more attention so that the riding cost will not be much lessened; but, of course, the greater attention produces the greater returns. While the cattle are on the home ranch the work of looking after them will be small, but the fences must be kept in repair, which is an added expense. Averaging figures from all sources, an annual charge of $1.50 for all riding, handling, and putting out of salt seems to be a fair and reasonable figure.

**Taxes.** Taxes on cattle are always an important item of expense, but one which varies with every locality. The rate of assessment is left to the judgment of the assessor, with the result that there is no uniformity in the practice of the different counties. Not only do assessments vary, but the levy may be two or three times as high in one locality as in another. Unfortunately a high assessment does not always go with a low levy, with the result that taxes on cattle in some counties are four to five times what they are in other counties. The variation between various localities and school districts is even greater. A careful study of taxes on cattle, made by the writer for the Oregon Cattle and Horse Raisers' Association, showed that in 1922 the average tax on cattle amounted to approximately 86 cents per head for all of Eastern Oregon. This will include taxes on miscellaneous equipment as well as cattle, but will not include taxes on grazing-land or hay land. This same investigation showed that the average tax on grazing-land in Eastern Oregon was 11 cents per acre and that there were approximately eight acres of taxable grazing-land per head of cattle, thus making the taxes on grazing-land 88 cents for each head of cattle. The valuation of $8.00 per ton on hay as previously given is supposed to cover all items of cost, labor, interest on land, taxes on land, etc. As a rule, however, the taxes on land enough to produce one ton of hay will run from 50 to 75 cents, with an average of 65 cents. The total taxes of all kinds relating to beef production would therefore total about $2.40 a head. Since the average turnover is a little under 24 percent, the total taxes paid by the cattle business of Oregon averages $10.00 for each beef animal marketed.

For further details of this tax question, the reader is referred to the annual report of the Oregon Cattle and Horse Raisers' Association for 1923.

**Summer grazing.** Much of the summer grazing in the Blue Mountain country is on the National Forest where, at the present time, the annual charge is running approximately 12 cents per head per month, and the average length of grazing season is 5½ months, giving an average cost of 66 cents per head.

**Spring and fall grazing.** The stockmen in the Blue Mountain district own a large area of foot-hill or sage-brush grazing-land for spring and fall use. The census figures for Grant and Wheeler counties indicate an average of ten acres of deeded pasture land for every head of cattle and this corresponds rather closely to surveys made through that country. It must be borne in mind, however, that not all of the cattle or sheep are taken into the National Forest or other mountain pasture. This foot-hill land, therefore, maintains some stock throughout the season. In addition to the deeded land there are small tracts of government land open to homestead, but this land is isolated, generally rocky rims, or other land of very little value and used mostly by sheepmen, since they can use these isolated, unfenced tracts where the cattlemen cannot. This land is not much of a factor in the cattle business and the bulk of the spring and fall grazing must be obtained from the deeded land. For cattle that go into the National Forest or mountain pasture 8 acres of deeded foot-hill land is enough, while the cattle that are kept on such land throughout the season need 15 to 20 acres.

Grazing-land has fluctuated greatly in value. The first grazing-lands homesteaded usually controlled a certain amount of water and consequently sold for a higher price than the grass on them would justify. Other homesteads were bought out because they were in the way. Finally, when the entire country was taken up, it was found that many tracts that were supposed to control other land no longer exercised such control and must be valued on the basis of what they would produce. A few years ago good foot-hill grazing-land was commonly priced at $10.00 an acre, and if especially well located, as high as $12 or $15 an acre. Since the depression in cattle prices, the price of land has been going down, although not many sales are made. It is possible at the present time by looking around carefully to purchase very good land for grazing purposes at $6.00 to $8.00 an acre. We do not assume, however, to say that this is the correct or proper value of this land. Most operators have this much or more actually invested. On the other hand, cattle grazing produces no net income at present cattle prices. Our cost records show that the operating costs equal or exceed the returns from the cattle, leaving no margin as income from the grazing-land. Likewise, we know that there are thousands of acres leased for the taxes at from ten to twelve cents an acre. Any market value which this land has at the present time (October, 1925) is, therefore, based upon the hope of the future, and not upon present known facts. If cattle prices should advance to the same level with the other commodities—in other words if steers should sell at approximately ten cents a pound on the farm—the valuation of $6.00 to $8.00 an acre would be justifiable. In the long run, the value of grazing-land must depend upon the returns which can be obtained from it, and since the running expenses do not correspond particularly with the price of cattle, the margin left as income on the investment must fluctuate even more than the price of stock. The value of deeded grass, moreover, depends to a considerable extent on its accessibility to National Forests or other cheaper grazing. A loss of free grazing privileges or an increase of grazing fees would depreciate the value of deeded land.

Interest rates on land of any kind can seldom if ever be high. When the productive value of land is once known, it will seldom pay a higher rate of interest than would good bonds, and the possibility of an increase in value will also be considered as a part of the income. We would, therefore, consider 5 percent as a fair interest on land.

**Interest on investment in livestock.** The capital value of the livestock investment is figured as nearly as possible at the cost of production, as this is the real investment. The cost of production, as we are well aware, is much above the present market prices and it would be possible for a beginner to buy stock cattle on the basis of current market prices at much less than the cost of production, but that would be merely passing a part of his individual loss back to the man who raised the cows, or to use the old expression, it would be "robbing Peter to pay Paul."

There is considerable variation in the interest rate, but we feel that 8 percent is about a proper allowance in the way of true interest. It is, of course, a fact that many of the banks charge 9 percent and 10 percent, and it is also a fact that the cattle loan companies charge 9 percent to

9½ percent or even 10 percent interest, but in such cases the lender lends a very large proportion of the value of the herd and is obliged to take so much risk that evidently a considerable portion of this interest is scarcely interest in the true sense of the word, but rather a part of the risk of the investment. We do not believe it reasonable to expect any industry to pay an interest rate in excess of 8 percent. It is unfortunately true, however, that the cattle and sheep industries are at the present time charged the highest rates of interest known in the commercial world. This is largely due to the fact that the loan companies have no way that is not both expensive and unreliable of inspecting the security. The loans are also often so large that when there is a depression the loan companies have to stand a large share of the losses. When times are prosperous, lending on livestock at 9 percent and 10 percent is very profitable; at other times it is disastrous.

**Income.** The income to be derived from a herd of cattle depends upon the calf crop, quality, weight, and market price of the animals sold, and the death losses. Each of these items is of sufficient importance to receive separate consideration.

**Losses.** The losses are irregular, varying much from year to year. They are also very difficult to ascertain since most cattlemen do not count their cattle with sufficient accuracy to be sure on this point. In bunches of a hundred or less one man may lose none, while another will lose ten to fifteen. In a survey made seven or eight years ago most of the cattlemen figured that 1 to 2 percent would easily cover all their losses on cows; 3 percent on calves; and 1 percent on older steers. A further study of this matter, however, indicates that the losses are unquestionably very much higher than this, and that 3 percent is about the lowest loss which we can ordinarily expect with cattle under range or semi-range conditions, and that the loss may increase from this on up, in some cases as high as 8 and 10 percent. The chief sources of loss are: (1) the loss of cows at calving time, particularly young heifers; (2) the loss of cattle from various poisonous plants; and (3) the loss from straying, particularly on the summer ranges. Another source of loss in some localities is blackleg among calves but vaccination and care will very largely prevent this loss. Aside from this, disease is not a serious factor in beef raising, as it is in other lines of livestock. In the case of steers past one year of age, the loss from disease is almost negligible.

A recent survey of losses in this district showed losses ranging from 2 percent to 10 percent with an average of about 4.3 percent. On the other hand, figures on losses supplied by the National Forest Service showed an average loss for the same district of 8 percent. The latter loss may be slightly exaggerated, but the figures given in our survey may be somewhat low, owing to the tendency of many stockmen to forget the full extent of their losses. The losses at the Eastern Oregon Experiment Station for steers wintered on hay and run on the National Forest in the summer, show an average loss of 3 percent, most of which has been due to straying or to bloat on alfalfa pasture in the fall. It is believed that under good management the annual losses can be cut down to 3 percent in all except unusually unfavorable conditions, and that the average loss at the present time is actually about 5 percent and perhaps higher, rather than lower than that figure.

**Calf crop.** The number of calves per 100 cows is the vital factor in the cattle business. Poorly managed herds under bad conditions are getting a calf crop of only 50 percent, while under the best conditions the average may be as high as 75 percent, even under strictly range conditions. Of course, even these figures will vary greatly in good and bad years. The average calf crop in Oregon is about 65 percent; that is, from 100 cows bred this year 65 calves may be weaned next year. This figure has been checked from many angles, and it is not far from the true average. This same figure will apply to all of the Rocky Mountain country. In the desert country the percentage is lower, and in Arizona and New Mexico it is apparently less than 50 percent on the average, varying from 20 to 65 percent according to the year. Cattle bred and handled in small pastures, on the other hand, will produce about 10 percent higher calf crop than range cattle.

## PERCENT OF TURNOVER

By "percent of turnover" is meant the number of cattle that may be sold each year out of each 100 in the herd. This in turn depends upon the percentage of loss, the percentage of calves, and the age at which the steers are sold. It is determined as follows, where the annual loss is 5 percent, the percentage of calves 65 percent, and the steers sold as two-year-olds. For convenience, the figures are based on a herd in which 1000 cows are bred each year.

| | | Inventory, fall 1925 | Losses during year at 5% | Inventory, fall 1926 |
|---|---|---|---|---|
| Breeding cows | | 1000 | 50 | 950 |
| 1926 calf crop, steers | 65% at weaning | -------- | ---- | 325 |
| 1926 calf crop, heifers | | -------- | ---- | 325 |
| 1925 calf crop, steers | | 325 | 16 | 309 |
| 1925 calf crop, heifers | | 325 | 16 | 309 |
| 1924 calf crop, steers | | 309 | 15 | 294 |
| 1924 calf crop, heifers | | 309 | 15 | 294 |
| Total inventory | | 2268 | .... | ...... |

At the end of the year, the 294 two-year-old steers are sold or ready to sell. The 294 two-year-old heifers might be sold, but if the standard of the cows is to be kept up they should all be put into the breeding herd. These heifers, added to the 950 cows, will bring the cow herd up to 1244, but if 244 head of dry cows and inferior stock are taken out and sold, the breeding herd will be brought back to 1000 head. Out of a total of 2268 cattle, therefore, there can be sold each year (with a 5 percent death loss and a 65 percent calf crop), 294 head of two-year-old steers and 244 cows, or a total of 538 head, and yet keep up the herd. Thus each year are sold 538 out of 2268 or 23.7 percent of the herd. Therefore, the "turnover" in this case is 23.7 percent.

If the steers are not sold until they are three years old, the inventory would be increased by the number of two-year-olds carried over into the third year. The sales would be the same except for the death loss of carrying the steers another year. The situation would then be as follows:

### SELLING THREE-YEAR-OLD STEERS

| | |
|---|---|
| Inventory as above | 2268 |
| Three-year-old steers held over to sell as threes | 294 |
| Total inventory | 2562 |
| Three-year-old steers to sell (294 less 5 percent loss) | 279 |
| Dry cows to sell | 244 |
| Total sales | 523 |
| Percent of turnover | 20.4 |

Since it is something of a mathematical problem to figure out the percentage of turnover, the accompanying table is presented to show at once what the turnover will be under any given condition. This table will be found not only useful as reference, but worthy of study in showing the influence of death loss, calf crop, and age of selling on the turnover.

### PERCENT OF TURNOVER

*To find the number of cattle including both steers and dry cows that may be sold annually from a herd of 100 head, all ages, turn to the column showing your percent of death loss; follow down to the figure opposite your calf crop (at weaning) and that figure will be your answer. If the steers are to be sold at 2 to 2½ years of age use the first table. If the steers are sold at 3 to 3½ years of age use the second table.*

*Of the total number sold, slightly more than half (52 to 55 percent) will normally be steers and the remainder dry cows or heifers.*

### SELLING STEERS AS TWO-YEAR-OLDS IN NOVEMBER

| Losses calf crop | 2% | 3% | 4% | 5% | 6% | 8% | 10% |
|---|---|---|---|---|---|---|---|
| 50% | 23.3 | 22.2 | 21.3 | 20.3 | 19.4 | 17.5 | 15.5 |
| 55% | 24.3 | 23.4 | 22.5 | 21.5 | 20.6 | 18.8 | 16.9 |
| 60% | 25.4 | 24.5 | 23.6 | 22.6 | 21.7 | 19.9 | 18.0 |
| 65% | 26.4 | 25.5 | 24.6 | 23.7 | 22.8 | 20.9 | 19.1 |
| 70% | 27.5 | 26.4 | 25.5 | 24.6 | 23.7 | 21.9 | 20.0 |
| 75% | 28.2 | 27.3 | 26.4 | 25.5 | 24.6 | 22.8 | 21.0 |
| 80% | 29.0 | 28.0 | 27.2 | 26.3 | 25.4 | 23.6 | 21.8 |
| 85% | 29.6 | 28.8 | 27.8 | 27.0 | 26.1 | 24.3 | 22.5 |
| 90% | 30.3 | 29.5 | 28.5 | 27.7 | 26.8 | 25.0 | 23.2 |

### SELLING STEERS AS THREE-YEAR-OLDS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 50% | 20.4 | 19.5 | 18.6 | 17.7 | 16.8 | 15.0 | 13.2 |
| 55% | 21.4 | 20.5 | 19.6 | 18.7 | 17.8 | 16.0 | 14.2 |
| 60% | 22.2 | 21.3 | 20.5 | 19.6 | 18.7 | 17.0 | 15.2 |
| 65% | 23.0 | 22.1 | 21.3 | 20.4 | 19.5 | 17.8 | 16.0 |
| 70% | 23.7 | 22.9 | 22.0 | 21.1 | 20.2 | 18.5 | 16.8 |
| 75% | 24.4 | 23.5 | 22.6 | 21.8 | 20.9 | 19.2 | 17.5 |
| 80% | 25.0 | 24.1 | 23.3 | 22.4 | 21.5 | 19.8 | 18.1 |
| 85% | 25.5 | 24.7 | 23.8 | 22.9 | 22.1 | 20.4 | 18.7 |
| 90% | 26.0 | 25.2 | 24.3 | 23.5 | 22.6 | 20.9 | 19.3 |

When the percent of turnover, together with the cost per head of running the herd is known, the total cost per animal sold can be readily determined; for example, as has been previously shown, the average annual cost per head is $21.40 for each head of cattle in the herd. Through most of the Blue Mountain country the calf crop is about 65 percent and the death loss 5 percent. This would mean that, under these conditions, the turnover would be 23.7 percent, and the total cost, therefore, of each animal sold would be $90.30 ($21.40 ÷ 23.7 = $90.30). This cost, of course, would apply to two-year-old steers and to dry cows. In this case the percentage of two-year-old steers would be about 55 percent, and the other 45 percent would be dry cows. There is, of course, not an entirely satisfactory way of splitting up this cost between the steers and the cows. One could credit the herd with the selling price of the cows and then charge the steers with the remainder. This, however, is hardly fair, since it would be putting all the profit and loss on the steers, while in reality beef production is just about as much that of producing cows as it is producing steers, and it is not possible to produce one without the other.

The influence of a good calf crop and a low death rate is shown in the percent of turnover and from that in the cost of production. For example, with a 75 percent calf crop and a 3 percent death loss, the turnover is 27.3 percent, which would reduce the total cost per animal sold from $90.40 to $78.39. This high percentage of turnover is not an impossibility to the best of the Eastern Oregon cattlemen. On the other hand, there are many calf crops of only 50 percent and death losses running up to 8 percent. This would mean a turnover of only 17.5 percent and would increase the cost per animal sold to $122.90.

## COST OF MAINTAINING CATTLE OF DIFFERENT AGES

The preceding cost estimate is for a mixed herd containing the normal percentage of cows, calves, yearlings, etc., to sell steers as two-year-olds. The costs, however, might be separated so as to deal independently with cows, calves, and yearlings. The cost of running cattle of different ages is not far different except for the bull charges, which must be considered in connection with the cow herd. The interest charges are slightly less on running calves from weaning until 18 months of age, and the hay requirements are also less. This is why the steers of 18 months of age bring a lower price per pound than at other periods of their lives. It should be borne in mind, however, that only one-half the cattle are steers and that the other half are heifers. The cost of the heifers is the same but the selling price is often about $1.00 to $2.00 less. Usually heifers all go into the breeding herd and dry cows are sold in their place, but that does not change the situation.

In the Blue Mountain country, the tendency is to keep the cattle from birth to maturity on the same ranch and there is really no reason for doing otherwise. One part of the animal's life is about as profitable as another. The number of pounds of beef produced per annum is, under present conditions, about the same. In October, spring calves will weigh about 450 pounds, and at the rate of two calves for every three cows, this means 300 pounds of beef produced for each cow maintained. At 18 months of age this steer will have added 300 pounds and will weigh about 750 pounds, and at 30 months of age will have gained another 300 pounds and will weigh 1050 pounds. The heifers, however, will weigh considerably less than the steers. These figures are for cattle of good breeding, given about a ton of hay during the winter, and about all the grass and mountain range they can consume during the summer. Where the grazing is short at any season of the year, the gains will be less than have been indicated. The average steer in the Blue Mountain country does not weigh 1050 pounds at 30 months of age, probably lacking 50 to 75 pounds of this weight. Those which have received good care, however, will weigh 1050 pounds and yet keep the feed and expense bill within the budget indicated. These figures are therefore representative of good management—management which is a little better than the average but yet not ideal.

## COST OF MAINTAINING A COW

### October to October

| | | |
|---|---|---|
| Losses on cows, 5% of $75.00 | $3.75 | |
| Hay for winter, 1 ton at $8.00 | 8.00 | |
| Cost of feeding hay at $1.00 per ton | 1.00 | |
| Bull charges | 1.48 | |
| Salt | .25 | |
| Riding and putting out salt | 1.50 | |
| Taxes on cattle at 86c per head | .86 | |
| Taxes on 8 acres of grazing-land @ 11c per acre | .88 | |
| Forest grazing fees, 5½ months @ 12c | .66 | |
| Total running expenses | | $18.38 |
| Interest on cows, 8% of $75.00 | $6.00 | |
| Interest on 8 acres of land @ $7.00 an acre | 2.80 | |
| Total investment expenses | | 8.80 |
| Total expenses of all kinds per cow | | $27.18 |
| Total expenses of all kinds per calf @ 65% | | $41.82 |

## COST OF MAINTAINING A CALF FROM 6 TO 18 MONTHS

| | | |
|---|---|---|
| Hay for winter, .9 ton at $8.00 | $7.20 | |
| Cost feeding hay at $1.00 per ton | .90 | |
| Salt | .25 | |
| Riding and putting out salt | 1.50 | |
| Taxes on cattle at 86c per head | .86 | |
| Taxes on 8 acres of grazing-land @ 11c per acre | .88 | |
| Forest grazing fees, 5½ months @ 12c | .66 | |
| Total running expenses | | $12.25 |
| Interest, 8% of $41.82 | $3.35 | |
| Interest on 8 acres of land @ $7 an acre @ 5% | 2.80 | |
| Total investment expenses | | 6.15 |
| Total expenses of all kinds | | $18.40 |
| Initial cost of calf | | 41.82 |
| Total | | $60.22 |
| Probable death loss of 5% | | 3.01 |
| Total net cost at 18 months | | $63.23 |

## COST OF MAINTAINING A STEER 18 TO 30 MONTHS

| | | |
|---|---|---|
| Hay for winter, 1.1 ton at $8.00 | $8.80 | |
| Cost of feeding hay at $1.00 per ton | 1.10 | |
| Salt | .25 | |
| Riding and putting out salt | 1.50 | |
| Taxes on cattle at 86c per head | .86 | |
| Taxes on 8 acres of grazing-land @ 11c per acre | .88 | |
| Forest grazing fees, 5½ months @ 12c | .66 | |
| Total running expenses | | $14.05 |
| Interest, 8% of $63.21 | $5.06 | |
| Interest on 8 acres of land @ $7 per acre @ 5% | 2.80 | |
| Total investment expenses | | 7.86 |
| Total expenses of all kinds | | $21.91 |
| Initial cost of yearling | $63.21 | |
| Probable death loss of 5% | 4.26 | |
| Final cost at 30 months | | $89.38 |

## SUMMARY

| | Cost per head | Per cwt. |
|---|---|---|
| Cost of maintaining a cow one year | 27.18 | ..... |
| Cost of calf at 6 months of age at 65% calf crop with estimated weight 450 lbs. | 41.82 | 9.29 |
| Total cost of steer or heifer at 18 months of age with estimated weight 725 lbs. | 63.21 | 8.72 |
| Total cost of steer or heifer at 30 months of age with estimated weight 1,000 lbs. | 89.38 | 8.94 |

This method of determining the cost gives a final figure $89.38 for a two-year-old as compared with $90.40 by the other method of figuring. This is accounted for by slight differences in the way in which depreciation, death loss, and interest are handled. Since there seems to be no accurate method of calculating down to the last cent the cost of beef production, $90.00 is given in the summary as the final cost of the two-year-old steer or heifer.

## COST OF CATTLE RUN ENTIRELY ON FENCED DEEDED LAND

Some cattle in the Blue Mountain country are run entirely on deeded land. This requires from 15 to 30 acres for each head of cattle, depending on the kind of land. The average will be about 18 acres. The investment is higher in this case, but the losses are somewhat less and the calf crop higher. The quality of the feed is not usually any better than where the cattle go into the mountains, hence the weight and value of the cattle sold is about the same.

### RUNNING EXPENSES

| | | |
|---|---|---|
| Hay for winter, 1 ton at $8.00 | $8.00 | |
| Cost of feeding hay at $1.00 per ton | 1.00 | |
| Bull costs | .65 | |
| Salt | .25 | |
| Riding and putting out salt and miscellaneous | 1.50 | |
| Taxes on cattle at 86c per head | .86 | |
| Taxes on 18 acres grazing-land at 11c per acre | 1.98 | |
| Total running expenses | | $14.24 |

### INVESTMENT EXPENSES

| | | |
|---|---|---|
| Interest on cattle, 8% of $50.00 | $4.00 | |
| Interest on 18 acres of land @ $7 an acre @ 5% | 6.30 | |
| Total investment expenses | | 10.30 |
| Total running expenses and investment expenses | | $24.54 |
| Total per head of cattle sold at 25.5% turnover (4% loss and 70% calf crop, see page 14) | | $96.22 |

This statement indicates that cattle can not be raised entirely on deeded land at as low a cost as where they go onto the National Forest. The only way in which costs can be made comparable is by reducing the valuation of the deeded land that does not have forest grazing privileges.

There are not many herds handled under exactly the conditions budgeted above. Many users of the National Forest and other mountain grazing keep a part of their cattle on the home ranch. They often find that the home pastures will carry a few cattle through the summer, one head to 20 to 40 acres, for instance, without greatly lessening their carrying capacity during the spring and fall. Many also follow the practice of keeping their steers in fenced pastures and sending the cows to the mountains. In those cases the final cost is a joint cost lying somewhere between the costs given above and the figures given for cattle running on the National Forests.

## LEASED LANDS

The above budgets have all been made on the assumption that the deeded land was the property of the cattleman. The fact is that about half of the deeded foot-hill and sage-brush land in the territory under discussion belongs to other persons than ranchmen; that is, to homesteaders, land speculators large and small, road companies, banks, loan companies, etc. These lands are priced at prohibitive figures, presumably on hope, but in the meantime they are leased to the stockmen. The price of the lease at the present time seldom pays any interest on the investment; in fact, a very common price is the exact amount of the taxes. The cattleman who is using these lands is thereby able to pass a part of his loss on to the landowner. The loss is not lessened in any way by this process, but is merely divided up among more people. The owner of cattle-grazing land who leases his land to actual cattle operators is a party to the beef-producing business and entitled to a fair remuneration.

Fig. 3. Free range in southeastern Oregon.

## COST OF BEEF PRODUCTION ON FREE RANGE

In the southeastern part of Oregon, there is an immense area of free range. This area includes most of Malheur and Harney counties, together with the eastern half of Lake county and the southeastern part of Crook county. The entire district covers from fifteen to sixteen million acres; however, there is within the area nearly two million acres of fenced grazing-land, hay land, and farm land, leaving approximately fourteen million acres of free range. Of this free range, eleven and one-half million acres is public domain and a little over one-half million acres is state land. The remainder is mostly deserted homesteads lying open without control and grazed by the stockmen in the same manner as the public domain.

Although designated as a free range country, the cattlemen all own or control some grazing-land and taxes and interest are figured in our estimates on four acres of such land, which seems to be about the average amount used by the cattlemen who depend primarily on the free range. The hay in this region is mostly wild hay and, on the average, is not as good as alfalfa, but the cost of production is less.

Necessarily the calf crop is lighter under these conditions. Also the cows and steers weigh less and are worth less per pound. The death losses, however, do not seem to be any heavier in the desert country of Oregon than in the mountains. Since the steers do not get large enough to market as two-year-olds, they commonly have to be held over until they are three-year-olds, hence the turnover is less.

An estimate of expenses and receipts follows:

### COST OF RUNNING A MIXED HERD ON FREE RANGE

October to October

| | | |
|---|---|---|
| Hay for winter, 1 ton at $6.00 per ton | $6.00 | |
| Cost of feeding hay at $1.00 per ton | 1.00 | |
| Bull costs | .65 | |
| Salt | .25 | |
| Riding and putting out salt | 1.50 | |
| Taxes on cattle at 86c per head | .86 | |
| Taxes on 4 acres grazing-land at 11c per acre | .44 | |
| Total running expenses | | $10.82 |
| Interest on cattle 8% of $50 | $4.00 | |
| Interest on 4 acres land @ $7.00 an acre @ 5% | 1.40 | |
| Total investment expenses | | 5.40 |
| Total all expenses | | $16.10 |

The expense bill in the free range country is quite low on the basis of the cost per head of the entire herd, but on the basis of the cattle sold, it is quite another matter. Since the calf crop is only 50 to 55 percent, and the steers are not beef until they are three years old, the turnover is low. With a 50 percent calf crop the turnover is 17.7 percent, which would make the cost per head sold $90.96. Where the calf crop can be raised to 55 percent the cost per head sold would be $86.10. The true figure is probably somewhere between these two; in other words, the final cost is not materially different from what it is in the regions without free range. There are, in fact, a great many cattlemen in the free range country who are using much more deeded land than the four acres indicated. This increases the cost of running the herd, but it also increases the turnover, so that the cost of 100 pounds of beef is not far different. This country is, on the whole, rather better for cows than for steers and some steers are sold as calves or yearlings rather than being kept to maturity; this, however, is not the general practice. On the whole, there is no evidence that the cattlemen in the free range country have any advantage over the cattlemen in the Blue Mountain country, where the range is practically all under some form of control.

## COST OF WINTER BEEF

All of the previous figures have been for grass-fat beef marketed in the late summer or fall from grass. Where cattle are held into the winter after the grass season, the cost increases, since the gains that are made on hay are not sufficient to pay for the costs. With good alfalfa at $8.00 a ton, it is safe to figure that the cost of cattle fed on hay will increase at the rate of 35 cents per hundredweight for each month they are on feed. Cattle, for example, that have accumulated a cost bill of $9.00 per hundredweight at the end of a grass season will, at the end of four months' hay feeding, reach the total cost of $10.40. The increased cost per hundredweight is practically the same whether the cattle are fed merely hay enough to hold their own, or whether they are given all they will eat, but of course, those which are given all they will eat will improve slightly in condition so that the chances of getting this increased cost out of them will be better than in the case of those that have been merely roughed through.

The figure of 35 cents a month given above is based upon several years of experimental work both in wintering cattle and in fattening steers at the Eastern Oregon Branch Experiment Station. The data on these experiments are given in Oregon Experiment Station Bulletin 182, Growing Steers, and in Oregon Experiment Station Bulletin 198, Fattening Steers for Market.

## REDUCING COSTS

In studying the costs of producing beef, the chief concern is where and how these costs may, if possible, be reduced. In the first place, it should be understood that the costs given in this bulletin are based upon reasonably good management and intelligent business methods. There are cattlemen in Oregon who are negligent in the care of their stock and slipshod in their business methods. Their death losses are heavy, their calf crop is low, and their marketable stuff is small and inferior. These cases of manifestly poor management, however, have been eliminated from the averages given in this bulletin. Their figures are, of course, very much higher than those which we have given. In addition to poor management, there are a good many cattlemen in the state whose financial position is such that they cannot possibly handle their business in the way their judgment dictates. Their management is bad and their interest rates excessive. Their costs likewise reach exorbitant figures and have not been included. The actual cost of production on the ranges, therefore, is more apt to run over rather than under those which are given herein. It is, however, possible in some cases to produce cattle at a somewhat less cost than has been indicated. Generally speaking, under Blue Mountain conditions, a calf crop of approximately 75 percent and a death loss of only 3 percent is a possibility; it is also possible, by good management of the grass (and not by excessive use of winter feed), to add 50 pounds or more to the weight of the cattle. The man who can do this, however, is an exceptional man and can command a substantial reward for his services wherever he goes. Adverse prices have tended to drive these good men out of the business, or to prevent them from entering in the first place. While the exceptional man may keep his costs below the figures given, it would be unfair to the rank and file of cattlemen to say they are bad managers because they have been unable to do so. On the whole they will do well to keep their costs as low as those given in this bulletin. In order to do this they will have to tend strictly to business and make very few mistakes. The depression in prices has also had its influence on costs. The first effect was to reduce costs by causing the cattlemen to eliminate every possible unnecessary expense and also to mark down any excess valuation which they had on their investment. The continuation of the depression, however, has tended to increase costs, not by increasing the operating expenses, but by lessening the turnover. Cattlemen have been financially unable to buy good bulls or even enough bulls of any kind. They have often been unable to buy feed or to put enough labor on the cattle to care for them properly. Consequently, the tendency has been for the calf crop to decrease, the death losses to increase, and the general quality of the cattle to deteriorate.

## SUMMARY OF THE SITUATION

The most conservative cost that can be put on beef production and allow interest on a reasonable investment, is $90.00 per head or $9.00 per hundredweight for two-year-old steers and dry cows mixed. Since the usual spread between steers and cows is about $1.75 per hundredweight, and since the sale cattle run about 55 percent two-year-old steers and 45 percent cows, a fair division of the cost places the cost of the steers at $9.75 per hundredweight and the cows at $8.00 per hundredweight. This is for grass cattle during the summer and fall, and is f.o.b. the ranch. The cost delivered in Portland would average $1.00 per hundredweight more. Steers produced for the winter market would likewise cost 35 cents per hundredweight more for each month they were held after the grass season. The whole situation may be summarized as follows:

TWO-YEAR-OLD GRASS-FED STEERS

| | Per cwt. farm price |
|---|---|
| Cost of production | $9.75 |
| Average selling price, 1922, 1923, 1924 | 6.25 |
| Loss | 3.50 |
| Average selling price, 1925 | 7.00 |
| Loss | 2.75 |

It might be assumed that in the above costs of production, interest was charged on an inflated value of grazing-lands. When all interest charges on grazing-lands are eliminated, however, the cost of producing grass-fed two-year-old steers was found to be $8.60 per hundredweight, and if interest is eliminated on grazing-lands and also on the entire livestock investment, which, of course, is a financial impossibility, the cost would be reduced to $6.50.

In the case of winter-fed steers, both the cost and the selling price are higher as indicated below:

WINTER-FED STEERS FOR APRIL DELIVERY

| | Per cwt. farm price |
|---|---|
| Cost of production | $11.50 |
| Average selling price, 1922, 1923, 1924 | 7.00 |
| Average selling price, 1925 | 8.50 |

The above cost of production covers the entire cost from birth to maturity. Often the winter feeders have been able to turn out steers for $11.50 but only because they have bought their feeders for less than the cost of production and thereby passed some of the loss back to the grower. Here, again, if the interest charges on grazing-land are eliminated, the cost will be reduced to $10.35 and if the interest is eliminated on both cattle and grass, the charges are reduced to $7.75.

During the past four years, there have been numerous arguments as to whether the price of cattle was sufficient to pay operating costs without interest of any kind. In other words, whether a cattleman who owned his cattle and land free of debt could keep even. The general consensus of opinion has been that he could not, but some few cattlemen claim that they can keep even under these conditions. The cost figures indicated above show that up until the current year the average selling price of steers has been less than the bare operating expenses, excluding interest of all kinds. During 1925, the price has improved somewhat and the producers are now getting slightly more than operating expenses, but not enough to cover interest on their necessary livestock investment, to say nothing of interest on land.

There seems to be a suspicion in the minds of many people not engaged in the cattle business that the present financial condition of the cattle business is due at least in part to excessive costs of production rather than to market prices, and admitting that cattle prices are low, they feel that even a fair price would not save the situation. The answer to this is found in the following facts: The average price of good grass steers f.o.b. the ranch in 1913 was $6.00 per hundredweight. According to the index figure put out by the United States Bureau of Labor, the average wholesale price of all commodities in August, 1925, was 160 percent of the 1913 price. If the price of cattle had increased in this same ratio, steers would be selling now (September 1, 1925) at $9.60 and good cows at $8.30 farm prices. These prices would pay the cattlemen operating charges and a reasonable interest on investment. Oregon Experiment Station Bulletin 219, The Cost of Producing Mutton and Wool on the Ranges of Eastern Oregon, shows that the cost of producing lambs on the ranges of Eastern Oregon is at the present time $10.00 per hundredweight, farm price, for fall delivery, even after we have credited the sheep with 40 cents per pound for the wool. This shows again that the cost of production of cattle is not excessive and that the cattlemen are producing meat more cheaply than the sheepmen have been able to do. All of these facts together demonstrate that the present situation in the cattle business is not due to an abnormal cost of production, but to a subnormal price of the finished product.

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